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Experimental Education Series

EDITED BY M. V. O'SHEA

SPECIAL TALENTS AND DEFECTS



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SPECIAL TALENTS AND DEFECTS

Their Significance for Education

BY

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New York

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TO
THE MEMORY OF
RUTH ELINOR STETTER
A GOOD TEACHER



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PREFACE

THIS book has proceeded haltingly, as must be evident in many places, for it attempts to explore and describe a field that is not well illuminated. The actual examination of those mental functions which are relatively dissociated from general intelligence has not been carried far by experimentalists. However, the problems have been sufficiently formulated, and enough evidence has been secured, to warrant attempts at gleaned implications for education, even now.

Mine is the comparatively humble task of bringing together in an ordered presentation the works of original investigators, in such a way that they will be available for application. The appeal of the data is above all to educators, but also, of course, to those who deal in any office with human beings.

The chief difficulty in organizing the subject has been to delimit it, as regards the psychology of the elementary school subjects on the one hand, and mental measurement on the other. It is not the purpose to cover either of these fields in the present volume. Yet so closely are they related to the study of special aptitudes in school children that it will be scarcely possible to obtain the very clearest view of what is here written without additional knowledge of these matters.

It will be observed, also, that there has been no attempt here to teach introductory psychology. It is assumed that readers of this volume will be acquainted with the vocabulary of elementary psychology. The time has definitely passed when it was either feasible or desirable to present all topics in a single volume. Those who would learn what modern educa-

tional psychology has to teach now expect, first of all, to equip themselves by study of a general introductory text.

The lists of references are selected, not complete. To present complete bibliographies of all works bearing immediately or remotely upon every topic treated would cumber the volume inexcusably. References have been selected for these lists because they are historically indispensable, because they contain information of fundamental importance, or because they summarize much previous work. I believe that the selection is such that from the books and articles listed it will be possible for the student who wishes to do so, to construct the complete bibliography and history of each topic, up to the present time.

The hundreds of teachers who have sat in the lecture room of Professor E. L. Thorndike will see how many guiding suggestions for this volume have come from that source. Professor W. A. McCall has given counsel on certain chapters. Many investigators and publishers have extended courtesies, which are acknowledged through the references, and to which attention is here gratefully directed. I am indebted to Dr. John S. Richards, Medical Superintendent of The Children's Hospital, Randall's Island, New York, and to Mr. L. L. Kolburne, student at Teachers College, for assistance in securing illustrative material for Chapter VII. Finally, I have enjoyed the advantage of editorial supervision by Professor M. V. O'Shea.

My chief hope for the volume is that it may contribute toward the welfare of school children compelled to attend upon prescribed education, without due regard for their idiosyncrasies of original endowment.

LETA S. HOLLINGWORTH

TEACHERS COLLEGE
COLUMBIA UNIVERSITY
May, 1923

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EDITOR'S INTRODUCTION

WHEN the writer of this introductory note began teaching, it was popularly believed that a pupil who showed special excellence in intellectual work or in some particular study owed his superiority to a faithful and energetic will which held him to his tasks until he had mastered them thoroughly. It was generally believed, also, that marked deficiency in school work as a whole or in a special subject was due principally to a lethargic or indifferent will which could not resist distractions and temptations to self-indulgence. In those days, pupils were upbraided and even physically chastised if they failed to prepare the lessons which were prescribed for them in any study. The writer has often seen pupils whipped because they failed in their spelling, arithmetic, reading, history, or grammar. When punishment was administered in the school it was frequently repeated in the home, since parents quite generally entertained the view that failure to perform intellectual tasks satisfactorily was due to negligence or laziness, and it was thought that the best way to correct such delinquency was to arouse the will, usually by means of dermal stimulation. In his early experience as a teacher, the writer never heard, either in training classes or in teachers' institutes, that pupils possessed special talents or defects which were certain to be manifested in their school work because they were established by native endowment which could not be modified to any large extent by rewards or penalties.

But we are gradually abandoning the view that either brightness or dullness in general or in special directions is due primarily to volitional control or the absence of it. During

the last few years, experimental studies have impressed the principle that individuals differ in their inheritance of special capacities. Dr. Hollingworth shows in this volume how far we have gone in the detection of special talents and defects, with particular regard to the work of the school. She shows in preliminary discussion what notions people have entertained regarding the nature of ability, and then she discusses methods of measuring ability, alike of a general and of a special sort. She discusses the bases for differences among individuals in ability in respect to various intellectual traits or functions. Then she presents in detail what is known to-day regarding special talents and defects as revealed in the more important subjects taught in the schools.

We believe in these times that the school should to the fullest extent provide opportunities for each pupil to develop his talents as completely and as rapidly as possible. It is still required in most public schools, though, that pupils in any group should be kept quite close together in their educational progress, even when they show marked differences in ability in particular subjects or in the entire work of the school. But the pressure is becoming constantly greater to arrange school programs so that pupils may go forward as rapidly as their abilities, either general or special, will enable them to do, while those who are deficient may receive help according to their needs. There are already a number of experimental schools and school systems in which the principle of individual differences in ability is recognized and applied to a greater or less extent. One may safely predict that we shall find a way in time so that the principle may be recognized and applied in all public schools.

Dr. Hollingworth's book lays a sound foundation for the differentiation of pupils in a school or classroom according to special abilities or deficiencies. It can be read by teachers

who have not had extensive study of educational psychology or statistical methods of investigating such problems as are treated in this volume. The book is written in a graceful style, and technical matters are discussed in an unusually clear, simple, and attractive way. It may be confidently asserted that any teacher who has charge of thirty or forty pupils — or a smaller or larger number — will be helped to understand individual traits of excellence or deficiency if she will read what Dr. Hollingworth has presented in this volume. It may be safely stated, also, that a teacher will be more sympathetic toward pupils who experience difficulty in mastering special subjects of study if she will become familiar with the facts and conclusions which this book contains.

M. V. O'SHEA

THE UNIVERSITY OF WISCONSIN
May, 1923

SPECIAL TALENTS AND DEFECTS

CHAPTER I

PRELIMINARY DISCUSSION

I. SPECULATION CONCERNING THE NATURE OF ABILITY

SINCE reflective men began to record their speculations, theories have been expressed concerning the nature and relationships of mental functions. Plato in *The Republic* contemplated the importance of knowledge in this field. "Come now and we will ask you a question: when you spoke of a nature gifted or not gifted in any respect, did you mean to say that one man will acquire a thing easily, another with difficulty; a little learning will lead the one to discover a great deal; whereas the other, after much study and application, no sooner learns than he forgets; or, again, did you mean that the one has a body which is a good servant to his mind, while the body of the other is a hindrance to him? Would not these be the sort of differences which would distinguish the man gifted by nature from the one who is un-gifted?"

In *The Republic* the use of mental tests to discover the caliber of the mind is foretold. "We must watch them from their youth upwards, and make them perform actions in which they are most likely to forget or to be deceived, and he who remembers and is not deceived is to be selected, and he who fails in the trial is to be rejected. That will be the way?"

Aside from the speculations of scholars, folk-notions as expressed in proverbs are interesting, especially as showing what men wish were true concerning human talents and defects. Many of these proverbs embody the idea of a compensatory distribution of abilities: if I am weak in one respect, I am sure to be strong in another; if I am a failure now, I shall probably be a success later on. "Every dog has his day." "Homely in the cradle, handsome at the table." "Slow but sure." "Easy come, easy go." This doctrine of compensation satisfies certain cravings of human nature, and is therefore likely to be held wherever people have not given impartial attention to the results of experimental investigation.

Folk-wisdom has also seen men under mental types. According to the theory of types, the human species is divided into separate categories, with respect to mental constitution. There would thus be the musical and the unmusical, the quick and the slow, the imaginative and the unimaginative, the eye-minded and the ear-minded, and so forth. The observable complexities of behavior have further led to the description of a given person by a combination of type-terms, as, for example, "quick-musical-imaginative," or "mathematical-accurate-unimaginative." Persons thus classified by types, are thought to be of "different kinds," "equal" but "unlike." Two persons are thus compared as an apple is compared to an orange. Both fruits are "equal," but of "different types." People, according to this conception of human nature, are not thought of as differing from each other simply in amount, as an apple is compared with a larger, a smaller, or a sweeter apple. Comparison in terms of amount is disagreeable in some respects, so that uncontrolled speculation would surely tend to favor the theory of distinct types.

Type-terms have also been invented for temperament, — sanguine, choleric, melancholic, phlegmatic. The idea underlying this classification is that everyone belongs to one or another of these distinct temperamental types, and, furthermore, that there is a relationship among types which warrants fixed hyphenated categories.

The mental traits or “faculties” thus classified and hyphenated are conceived as entities, having each its distinct existence in the individual mind, and being susceptible to general training and strengthening, by prescribed exercises. Thus it has been believed that “the observation” may be developed by exercises with particular materials, so that all materials whatsoever will be observed equally or approximately as well.

Speculation has been much occupied, as the history of human thought shows, with the problem of the origin of individual endowment. Many different possible explanations were proposed, before the day of quantitative measurement in psychology. It has been surmised that mental endowment is the result of prenatal influences, the wishes and environment of the mother, during the period of gestation; or that it is the result of education; or that it arises from the physical accidents met with by the organism; or that it may be inherited from ancestors, as physical traits rather obviously are. On the whole, speculation has favored the notion that mental endowment originates in the environment. The idea that ability is hereditary, determined for each by the conditions of ancestry, is repugnant. Man prefers to consider that he can himself determine what he will do and be. This doctrine will not be tenable if it is admitted that talents and deficiencies are determined in the germ-plasm, from which the organism springs; that man can only use, not choose, his mental endowment.

II. RESULTS OF QUANTITATIVE INVESTIGATION

Many of the cherished hopes and desires of mankind concerning itself are in some part violated by the teachings of scientific psychology. Experimental psychology is not yet half a century old, dating its beginning as a technical science from the founding of Wundt's laboratory at Leipzig, in 1879. Therefore, it is clear that the study of these problems by quantitative methods brings us very close to the present day.

When the problem of measuring mental capacity was first taken into the laboratory, the modern definition of a *mental function* began to be formulated. It became apparent that a mind must be judged by its product. The measurement of *performance* is the only approach there is, or probably ever will be, to the measurement of mind. On this basis it was found impossible to identify or measure any such function as "the reason," "the memory," "the observation," "the imagination," "the will," and similar supposed entities. A *mental function* came to be defined as "*an actually or possibly observable event in behavior.*" Thus, memorizing digits, detecting absurdities, and reading English print are examples of mental functions, in the sense in which the term is used throughout the chapters of this discussion.

Other terms which are used to refer to performances or "events in behavior," are *abilities* and *capacities*. A prolonged discussion might be conducted, in an attempt to assign different technical meanings to these words, and to bring out fine shades of distinction among them. For instance, it might be claimed that "ability" should be reserved to signify capacity *plus* the skill acquired by practice, if any; while "capacity" should mean the innate aptitude, apart from all training. However, since capacity in this sense can never be known, but can only be inferred from the degree of actual

performance, under controlled conditions, it hardly seems necessary to maintain such distinctions for our purpose. Refinements of nomenclature will, therefore, be avoided, and the terms *mental function*, *capacity*, and *ability* will be used interchangeably, to denote performance which depends on the inborn integrity and sensitivity of the individual.

By way of clarifying the definition of a mental function as "an actually or possibly observable event in behavior," we may quote from Spearman's presentation of the distinction between "observation" as a mental function, and "observation of birds' nests." Spearman says: "Suppose, for instance, that a school boy has surpassed his fellows in the observation of birds' nests. His victory has, no doubt, depended in part on his capacity for the general form of activity known as 'observation.' But it has also depended on his being able to apply this form of activity to the matter of birds' nests; had the question been of tarts in the pastry cook's window, the laurels might well have fallen to another boy. A further influence must have been exercised by the accompanying circumstances; to spy out nests as they lie concealed in the foliage is not the same thing as to make observations concerning them in the open light of a natural history museum. Again, to discover nests at leisure is different from doing so under the severe speed limits prescribed by the risk of an interrupting gamekeeper. The boy's rank may even depend largely on the manner of estimating merit. Marks may be given either for the gross number or for the rarity of the nests observed; and he who most infallibly notes the obvious construction of the house-sparrow may not be the best at detecting the elusive hole of the kingfisher." One cannot, therefore, identify and measure "observation." One can only measure "observing birds' nests, of all kinds, at leisure," or "observing rare birds' nests, under stress of pursuit,"

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and so forth, which are "actual or possible events in behavior."

As one may glean further from Spearman's discourse, it has been shown that most of the mental functions performed by men are not elementary, but consist of the coördination of complex factors, capable of analysis. Reading the English word "cat" from a printed page is, for instance, a very complex function.

The application of quantitative methods to the study of mental functions as thus defined, quickly revealed the fact that human beings, sampled at random, in large numbers, do not fall into distinct types. On the contrary, they yield one unbroken curve of distribution in the function measured, clustering around *a single type* (or mode). In all mental functions which have been measured, there has been found but one type — the average human type — from which the individual members of the species deviate in degree (though not in kind). The majority of individuals deviate but slightly from this biologically established type or mode. "The typical" in ability is, indeed, by definition, what the greatest number of people *can do*. From this performance of the *average* or *typical* person, a few individuals deviate widely in the direction of superiority, while a corresponding few deviate widely in the direction of inferiority. No doubt the conspicuousness, because of their infrequency, of extreme deviates in respect to any given function (or capacity) has led to the notion of separate types of mankind. Mental measurement shows clearly that men cluster closely around *one type* in mental traits, just as they do in such physical traits as height and weight. All men can be no more divided into the dull and the bright, than they can be divided into the tall and the short. The eye can see that most persons are best described as medium, in height.

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This principle of *one type*, with deviations in both directions from it, in a measured trait, holds throughout organic nature. The study of it in all its bearings is called the study of individual differences. When the traits involved are mental, we speak of the psychology of individual differences. It is one of the marvelous facts about human beings that of all the millions born, no two are just equal in possession of a given trait, except by chance; and no two are identical in their combinations of traits, for the infinite possibilities of permutation practically exclude identity by chance. These combinations, which go to make up *personality*, are combinations of *amounts* of the same traits. This must be clearly understood. The mental classification of men under different "kinds" is a myth. All show the same kinds of functions; but they show all degrees of performance in these functions, within limits which are extremely wide, with multitudinous possibilities of combinations of functions, in different *amounts* of each.

There are, therefore, not types. There is *one type* — the typical or *most frequently occurring amount* of performance in a function — from which there is divergence among the individuals born, in various degrees. Is it possible to construct a picture of this fact, so that it may become concrete through visual representation? Psychologists have given us many such pictures, in the forms of curves platted from their measurements. We may cite as an example, Seashore's curve of distribution for the ability to discriminate among intervals of time, which is one element in musical sensitivity. Seashore measured a large number of adults in this respect, with the result that is pictured in Figure 1.

Where the curve rises to its greatest height, at its peak, there the greatest number of those measured fall in respect to this function. That is, therefore, the human type, in

sense of time. The typical individual has that amount of this trait. On each side of the type fall deviating persons, their frequency decreasing rapidly as the amount of deviation becomes greater. Very few persons in ten thousand have that amount of sensitivity to time represented by 95–100; and, on the other hand, very few are so inferior as to fall at the lowest point measurable on this scale. *The typical person* has that amount of the trait represented by 85–75, approximately. Distinct types, such as “sensitive” and “insensitive,” do not appear, as a result of mathematical

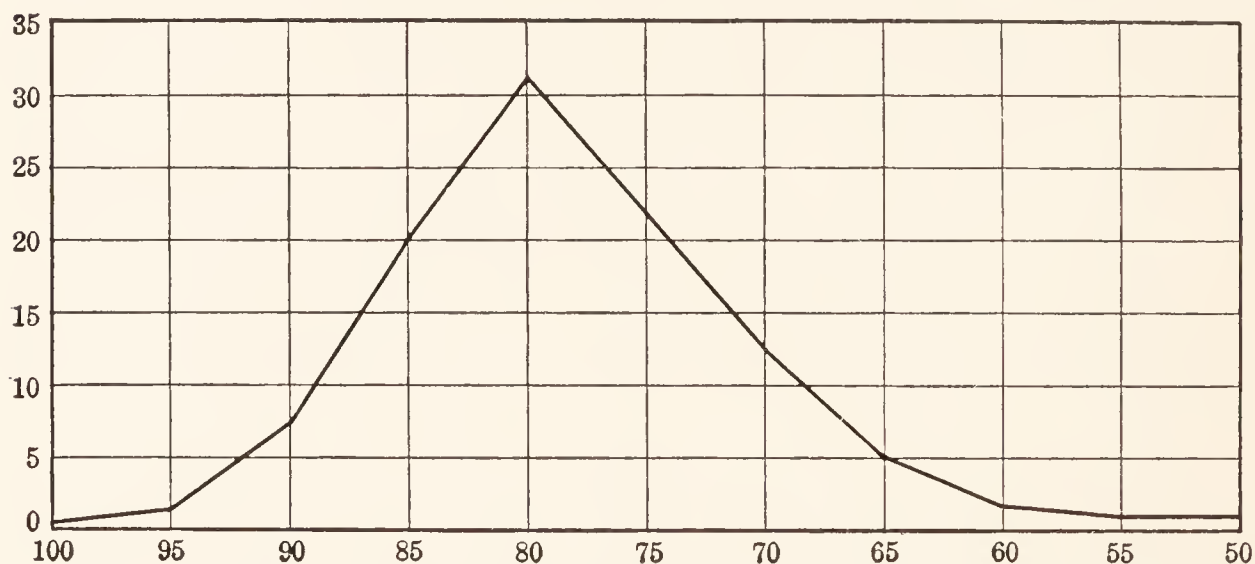


FIG. 1. — Distribution of ability to discriminate among intervals of time, the subjects being adults. (From Seashore's *The Psychology of Musical Talent*. Reproduced by courtesy of Silver, Burdett and Company, and of The Columbia Graphophone Company.)

distribution. But a few extreme *deviates from the typical* appear,—the superior in sensitivity and the inferior in sensitivity.

Occasionally it is possible to illustrate in nature, to the eye of the man untutored in the derivation of scientific laws, the form of this distribution. This happens, for example, when a very large flock of birds rises and passes overhead, during migration. Being tested in flight, the birds will be seen distributed somewhat as suggested in Figure 2. Not all are equally swift and enduring, but they deviate from a single

type or mode — the great median mass of birds, which are typical of this species, in respect to the function of flight.

The same phenomena of distribution appear if a thousand wild horses run a race, or if a hundred unselected swimmers swim in competition. They appear whenever non-select organisms of a single species are submitted to an adequate test or measure of any function of endowment. The curve approximates that form which mathematicians tell us results when an infinite number of factors act together in an infinite number of ways.

We have spoken thus far of the distribution of individuals in a single kind of performance. What does quantitative psychology teach with respect to the combination of per-



FIG. 2. — Flight of birds, illustrating distribution in ability to fly. (Schematic.)

formances in a given personality? Is it true, as folk-wishes would have it, that abilities are distributed among us by a law of compensation? Is the slow man's slowness offset by accuracy? Does the quick learner lose his learning more readily than the slow learner? Is he who excels in arithmetic likely to be surpassed at spelling? The general consideration of these questions, which form the topics of this volume, will be found in the chapter which follows. It will be seen that there is no law of compensation in human ability, however much we may long to find it there.

As for the origin of talents and defects, psychology teaches that mental endowment in human beings is conditioned by ancestry, just as other traits of organisms are. Mental capacities are inherited through the germ-plasm. A child is

gifted (if he is so) for the same reason that he is an Eskimo (if he is one) — because some or all of his ancestors carried those traits in their germ-plasm, and the combination of them in just that way was possible.

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CHAPTER II

THE RELATIONSHIPS AMONG CAPACITIES

I. THE COEFFICIENT OF CORRELATION

THE question is: How are mental capacities mutually related, with regard to amounts of each found in given individuals?

Before verifiable facts can be established in a field of knowledge, it is necessary to introduce therein methods of enumeration and measurement. The question above propounded has waited long for answer, because of the great difficulty of applying mathematics to mental phenomena. The answer required first that single functions be accurately scored, and then that a measurement be obtained of the *relationship* between and among the single functions.

It seems well agreed that the quantitative determination of the relationship between and among mental characteristics began with Galton, about 1885. Various scholars have presented discussions of the subject since then, notably Baerwald in 1896, Spearman in 1904, Stern in 1911, Meumann in 1913, and Thorndike in 1913, each of whom summarized the findings up to the time of writing, with original interpretations.

The methods of quantitative measurement used to study the constitution of mental abilities, or functions, as related to each other, are chiefly those of correlation — simple correlation, multiple correlation, and partial correlation.

It is not within the scope of the present volume to give consideration to these methods as such. Highly technical instruction in the theory and practice of measurement is necessary for complete understanding of them. The results may be comprehended for our purposes, without complete knowledge of the methods. Much of the evidence we now have in the matter of relationships among mental functions has been obtained by the method of simple correlation. A brief exposition of how a relationship is established between two variable functions within a group, by simple correlation, will suffice to give a general understanding of the term *coefficient of correlation*, which is used here, and which frequently appears in modern texts of educational psychology. The interpretation of coefficients of correlation should not, however, be undertaken independently without full knowledge, as competent interpretation for practical purposes must take into account all the conditions under which they have been derived.

Below are listed fourteen school children, each of whom has been measured in each of two mental functions: (1) mental age, determined by a standard scale for measuring general intelligence (Stanford-Binet), and (2) spelling ability, as measured by a standard spelling scale (Ayres' scale). These children were selected for study, because they appeared to be characterized by special discrepancy between the two functions.

We wish now to know whether and to what extent the child who falls high in the distribution of mental ages also falls high in the distribution of spelling ability. According to the formula which is most useful in this case,¹ we arrange these pupils in their order of merit for one of the functions

¹ $\rho = 1 - \frac{6 \sum d^2}{n(n^2 - 1)}$ Resemblance equals one minus six times the sum of the differences (in rank) squared, over the number (of cases) times the number (of cases) squared, minus one.

measured, *e.g.* for mental age. We then find the rank for each, within the group, in the second function, which is here spelling ability. The difference in rank between the paired functions is then found for each pupil, and the correlation formula is applied.¹

TABLE FROM HOLLINGWORTH

Showing rank in each of two mental functions, within a group of fifth-grade children, selected for special disability in spelling. The coefficient of correlation obtained is .081.¹

NAME	MENTAL AGE		SPELLING ABILITY PER CENT CORRECT LISTS Q AND R (AYRES)
	YRS.	MOS. (STANFORD-BINET)	
RL	13	7	90.1
JP	12	5	95.2
HA	12	2	81.7
MG	11	6	31.7
LK	10	10	80.2
SSh	10	10	77.9
SSc	10	9	81.8
MS	10	9	34.1
PJ	10	4	32.6
HL	10	1	58.9
RH	9	8	93.1
MU	9	8	57.0
BN	9	6	92.1
HR	8	3	81.8

If there is in fact perfect correspondence, so that each pupil holds the same rank on the distribution in both functions, a perfect positive correlation is obtained, the *coefficient of correlation* being expressed as 1.00. If no relationship at all exists between the two functions measured, so that nothing whatever can be predicted of either from knowing about the other, the coefficient of correlation will be 0.00.²

¹ $\rho = 1 - \frac{6 \sum d^2}{n(n^2 - 1)}$ Formula explained, opposite page.

² Thompson has recently shown that a coefficient of zero does not necessarily mean absence of relationship between two factors. There might be a strong influence making for negative correlation, and at the same time an equally strong influence making for positive correlation, which might, by just counterbalancing each other, produce a spurious effect of no connection at all, namely, a coefficient of 0.00.

If there exists a perfect negative relationship, so that the person who stands highest in one stands lowest in the other, and so forth through the series, in a perfect inverse standing of all members, then a coefficient of correlation expressed by -1.00 is obtained.

In the sample given, the coefficient of correlation obtained is $.081$, which not being reliably greater than zero (because of possible error due to the smallness of the group and other conditions) tells us that the two functions are in this case related to each other only very slightly, if at all. The child who stands above the average of the group in mental age, may or may not stand above the group average in spelling. With a relationship so far from unity as is expressed by a coefficient of $.081$, we may expect to find in this group comparatively intelligent children who are very poor spellers, and good spellers who stand low in mental age. Among children taken at random, however, a different relationship exists between spelling ability and general intelligence, as represented by mental age. The positive correlation is much higher among children not selected, as these were, for an observed discrepancy.

At the present time the more elaborate methods of partial correlation and multiple correlation are being applied to the study of relationships, where more than two functions are involved. Into the intricacies of these we shall not enter, except as concerns their results.

II. GENERAL INTELLIGENCE *vs.* SPECIAL APTITUDES

The original attempts to apply mathematical formulæ to the study of relationship among mental traits eventuated in divergent hypotheses. In England, Spearman, with his students and collaborators, interpreted his researches to mean that

there is in mental constitution a "general factor," which shows itself in all the performances of a given individual. This would render relatively predictable the quality of performance in all functions, from knowledge of performance in one function. "All branches of intellectual activity have in common one fundamental function (or group of functions), whereas the remaining or specific elements of the activity seem in every case to be wholly different from that in all others. . . . The function almost entirely controls the relative position of children at school (after making due allowance for differences of age), and is nine parts out of ten responsible for success in such a simple act as Discrimination of Pitch. . . . Its relation to the intellectual activity does not appear to be of any loosely connected or auxiliary character (such as willingness to make an effort, readiness in adaption to unfamiliar tests, or dexterity in the fashion of executing them), but rather to be intimately bound up in the very essence of the process."

Spearman noted that, though all functions seemed related to this "common factor," they were not all equally related in his results; wherefore he formulated the concept of a hierarchy of relatedness. Discussion as to the essential nature of the fundamental factor was reserved, but it was predicted from the correlations made that "general intelligence" could and would be measured for practical purposes. This interpretation was based upon the fact that among abilities which yielded to his measurement, Spearman could find only positive coefficients of correlation, when the groups were large and the human beings non-select.

In the United States, Thorndike and his collaborators were most struck by the fact that the coefficients obtained fell short, in many cases far short, of unity. They laid stress upon the imperfection of the relations revealed, and were able to show that between some functions, such as discriminating

among the lengths of lines, and others, such as naming the opposites of words, the correlation dropped in groups investigated to approximately zero.

As a result of interpretation from their point of view, they wrote as follows: "One is almost tempted to replace Spearman's statement by the equally extravagant one that there is nothing whatever common to all mental functions, or to any half of them." They maintained that mental functions are specialized, and that when excellence in one is correlated with excellence in another, "this is due chiefly to the fact that the two involve identical elements in their execution. It is not due to one and the same 'faculty,' which presides over their activities."

These two divergent interpretations of the same array of data have been cited, because the controversy involved is of first rate importance for mental measurement, for the understanding of individuals, and for education. The controversy now appears to have been one of emphasis. To recapitulate, Spearman stressed the positive aspect of the coefficients found, and declared mental traits to be distributed so that status in one is predictable from status in another. Thorndike emphasized the reduction from unity of the coefficients, and formulated the hypothesis that there is no absolutely predictable coherence among mental functions, that each is special to itself within an individual. No laboratory scientist has ever found reason for adding a third side to the controversy, by advocating seriously that mental traits are compensatory in relation to each other. Negative coefficients of correlation have never been found, except occasionally by chance or selection.¹ All know that the correlations among amounts of traits are positive. It is the reduction from unity which has caused the disagreements of interpretation.

¹ A curious case of negative correlation between cancellation and other tests has been reported by McCall (see references).

During the twenty years which have elapsed since the first interpretations were set forth there have been modifications of each hypothesis, in the direction of mutual reconciliation. This has come about through extended researches by many inquirers, furnishing additional data.

III. CORRELATION OF ABILITIES IN VARIOUS GROUPS

Some of the significant studies of correlation made since Spearman and Thorndike proposed their conflicting interpretations, have been cited in the appended list of references. Two samples of the results of these studies are herewith presented. The first is from Simpson's study of mental tests given to two groups of adults, chosen respectively from the opposite extremes of competency, as shown by social-economic success. One group was composed of successful professional educators. The other was composed of unskilled laborers and unemployed men. The table on page 18 shows how the traits measured cohere among these individuals. The coefficients are positive, in the majority of cases highly so.

The second sample is from Weglein's study of standing in school subjects, among high school pupils.

Bearing in mind that, if no mutual relationship exists among the abilities considered, coefficients of correlation will approach zero, it is clear that there is decided positive, but not perfect, correspondence. The wider the range of competence tested, the greater the correspondence found. High school pupils (from among whom those having very little ability for the subject matter taught have already been eliminated) show smaller coefficients than do the persons measured by Simpson. If all adolescents in existence were obliged to study the subjects listed by Weglein, and if the resulting grades were then correlated, the coefficients would be notably higher than those recorded.

TABLE FROM SIMPSON

PEARSON COEFFICIENTS OF CORRELATION (CORRECTED FOR ATTENUATION)

Correlations of abilities in two selected groups, and in the two treated as one group. In the case of each test the heavy-face figure given first is for the Good and Poor together, divergences being measured from the median of the 37 individuals. The second figure is for the Good group, divergences being measured from its median. The third figure is for the Poor group.

	EBBINGHAUS TEST	HARD OPPOSITES	MEMORY OF WORDS	EASY OPPOSITES	A TEST	MEMORY OF PASSAGES	ADDING	GEOMETRICAL FORMS	LEARNING PAIRS	COMPLETING WORDS	DRAWING LENGTHS	ESTIMATING LENGTHS
Ebbinghaus test . .		92	92	75	68	91	71	54	72	50	26	52
		66	67	48	03	42	55	00	22	67	-17	28
		90	78	90	76	61	63	36	73	71	27	01
Hard Opposites . .	92		92	81	76	86	74	64	72	70	25	55
	66		75	93	15	45	79	07	14	100	10	-08
	90		77	78	65	64	51	33	66	49	13	-02
Memory of Words .	92	92		68	70	89	56	67	82	51	06	59
	67	75		52	-13	41	20	06	53	100	-23	44
	78	77		70	88	100	23	56	44	43	-09	16
Easy Opposites . .	75	81	68		71	69	70	54	43	50	53	56
	48	93	52		05	05	45	38	-04	100	00	-02
	90	78	70		51	58	50	34	64	49	43	16
A Test	68	76	70	71		60	67	94	44	84	27	57
	03	15	-13	05		14	59	68	-16	04	-10	-11
	76	65	88	51		48	39	91	72	88	08	13
Memory of Passages	91	86	89	69	60		66	60	63	38	12	58
	42	45	41	05	14		20	-30	-26	35	-24	-36
	61	64	100	58	48		15	41	22	13	09	35
Adding	71	74	56	70	67	66		44	46	77	27	17
	55	79	20	45	59	20		13	12	86	-49	04
	63	51	23	50	39	15		19	51	70	05	-40
Geometrical Forms.	54	64	67	54	94	60	44		40	61	30	35
	00	07	06	38	68	-30	13		-23	00	40	-14
	36	33	56	34	91	41	19		39	32	14	07
Learning Pairs . .	72	72	82	43	44	63	46	40		34	04	54
	22	14	53	-04	-16	-26	12	-23		74	-38	61
	73	66	44	64	72	22	51	39		34	20	36
Completing Words .	50	70	51	50	84	38	77	61	34		17	22
	67	100	100	100	04	35	86	00	74		-04	06
	71	49	43	49	88	13	70	32	34		00	-28
Drawing Lengths .	26	25	06	53	27	12	27	30	04	17		55
	-17	10	-23	00	-10	-24	-49	40	-38	-04		-41
	27	13	-09	43	08	09	05	14	20	00		34
Estimating Lengths	52	55	59	56	57	58	17	35	54	22	55	
	28	-08	44	-02	-11	-36	04	-14	61	06	-41	
	01	-02	16	16	13	35	-40	07	36	-28	34	

TABLE FROM WEGLEIN

Coefficients of correlation between school subjects (teachers' marks) in the case of 59 high school pupils.

ACADEMIC GROUP

	ENG. I	ALG. I	HIST. I	LATIN I	DRAWING
English I . . .		.22	.20	.19	.37
Algebra I . . .	.22		.42	.65	.09
History I . . .	.20	.42		.57	.13
Latin I . . . . .	.19	.65	.57		— .22
Drawing . . . .	.37	.09	.13	— .22	

COMMERCIAL GROUP

	ENG. I	BKK.	COM. ARITH.	STENOGR.	TYPEWR.	DRAWING
English I . . . . .		.69	.52	.54	.50	.15
Bookkeeping . . . . .	.69		.66	.48	.50	.50
Com. Arithmetic . .	.52	.66		.38	.52	.53
Stenography . . . . .	.54	.48	.38		.51	.21
Typewriting . . . . .	.50	.50	.52	.51		.31
Drawing . . . . .	.15	.50	.53	.21	.31	

These are fair samples of the results of studies in correlation, among mental functions, in groups of individuals more or less select. Even physical traits, like height and longevity, have been found to give slight positive correlation with mental traits. Evidently there is a *general organic quality*, which shows itself to some extent wherever the individual is fairly tested or “sampled.”

IV. STUDIES OF DISORGANIZING MINDS

Another series of attempts at the solution of this problem has been made through observations upon deteriorating minds. The question is, Do mental functions deteriorate

together or separately in demented persons? When a person is "losing his mind," is the impairment general or selective in its progress?

The study of demented persons had been carried on by a few investigators in the hope that the decay of capacities might throw light upon their relationships. The chief obstacle to study from this approach has been that the investigators have never been able to know the original mentality of their subjects. They have always been obliged to make assumptions. It is difficult to see how this factor may be controlled, short of filing careful mental analyses of great sections of the population in youth. The chief conditions in which decay of ability is most probably present, as distinguished from decay of effort and attitude, are senile dementia, dementia paralytica, and alcoholic psychosis; and it cannot be known beforehand which persons are destined to represent these conditions. It cannot be predicted who will live long enough to become senile, who will contract syphilis, eventuating in general paresis, or who will be a chronic alcoholic. It is true that original mental status may be inferred with a moderate amount of accuracy from school status attained. If the demented studied had all been high school graduates, for instance, then we could be certain that the performances shown in the recorded studies really represent deterioration.

Unfortunately, the subjects of study have been, with rare exceptions, persons of elementary education and humble social status. They come from those sections of the education-occupation distributions, where very limited capacity is found. Therefore, we are rather uncertain as to how much deterioration from original status has really taken place. So far as actual figures go, it is not shown that there has been decay of intellect.

However, assuming that these segregated persons had actually deteriorated in their ability to perform tasks, let us inquire what the researches show. Binet and Simon worked with forty adults, classified as senile demented or as victims of dementia paralytica. They conclude that "Every demented has an intellectual level below normal," as measured by tests of general intelligence. The limitations of demented are, nevertheless, *qualitatively* different from those of other incompetents (children and the feeble-minded); and the reactions of the senile differ from those with dementia paralytica. Of the victim of dementia paralytica they say, "He has not tumbled down the ladder of development, rung by rung. His is a *difficulty of functioning*." "It is characteristic in these losses of functioning that the subject knows how to meet the problem submitted to him; he has the knowledge, but from time to time the power fails him." This *inertia* of comprehension is *general*, and has the effect of lowering the total level of performance, though the particular items of failure and success may vary markedly from occasion to occasion. It is hardly the same thing as actual decay of a structure. Thus one cannot predict the responses of these demented, as one can those of other incompetents, like children and imbeciles, because their errors and failures have a remarkable degree of inconsistency. "In a general way, one can hardly foresee how such a one is going to conduct himself, for special failures and successes are at such variance with the general level." "General paralytics are hardly able to perform the hundredth part of what they know."

Senile demented are different, in that they actually no longer know. The structure itself has been demolished, not merely has it been paralyzed as to function. According to the observations of Binet and Simon the abilities of senile demented as a group are by no means equally impaired. They

cannot remember events nor learn new things, yet they retain the power of auto-criticism, many complaining that they no longer "know anything." They may be degraded to the level of early childhood in ability to repeat digits, yet retain use of the vocabulary of a superior adult.

These observations are extremely suggestive, but they lack statistical validity, being limited to narrative descriptions. It is true that one who has worked much among demented in a practical way, recognizes the pictures drawn by Binet, of persons decayed in some functions, yet "surprisingly preserved" in others. Proof of the extent to which this characteristically happens would necessarily be derived from tests of large numbers of cases, treated mathematically, and not by the method of narrative.

Hart and Spearman more recently presented a study of sixty-one insane persons,¹ asking the question, "Does an insane person present, as a rule, much greater inequality of performance than a sane one?" Recognizing the error from not knowing the original status of the presumably deteriorated minds, in all the various functions to be tested, the attempt was made to allow for this by testing in the same way thirty-three sane persons, selected presumably to represent what the insane were like before they became alienated. Nineteen mental functions were thus tested, and the results were then treated by the method of correlation, the assumption being that if there were greater inequality among mental functions in the insane (that is to say, among deteriorated minds) than among the sane, this would show itself in diminished coefficients of correlation.

It is interesting to consult the original tables of data, which, however, will not be presented here. The conclusion reached

¹ "Insanity" and "dementia" seem to be synonymous, as used by Hart and Spearman. But in American texts "dementia" is limited to mean intellectual deterioration.

is that "The inequality between the powers of the same person for different kinds of performances does not appear to be appreciably greater in insanity than in health, nor in one of the forms of insanity tested than in another. Thus, in the main, the mental injury appears to be of a perfectly diffuse character, or to constitute a lowering of the whole intellectual level . . . Over and above this general impairment, elaborate methods can also detect certain damages characteristic of particular maladies. These are very narrow and specific in kind, but probably may be correspondingly grave in intensity."

Spearman thus again maintains his "two factor" theory of endowment — the "general factor" conditioning performance as a whole, and "specific factors" conditioning certain mental functions to a much greater extent than others. To determine what these special mental functions are, Spearman leaves to further research.

This careful investigation is nevertheless imperfect for the purpose, which is to learn whether there is selective enfeeblement of abilities. It is really impossible to know that deterioration *has* occurred, unless there have been measurements made beforehand. Sane persons, selected from the same social stratum, are not entirely reliable as a control, because those who are of the psychic constitution destined for insanity undoubtedly differ originally from those who remain sane, and this difference may involve a difference in mental abilities, either of amount or of relationship. The degree of deterioration calculated by Hart and Spearman may be merely a matter of original differences in central tendency between the two groups.

Here, too, it should be noted that Hart and Spearman mixed a variety of psychoses (even including an imbecile not deteriorated so far as known), both those that do involve actual

decay of ability, and those that involve only disturbances of general auxiliary functions, like attitude and effort. Just what would be the effect of this mixing upon the correlations could be told only if we knew how each form of disorder characteristically affects the relationship among mental functions, which is unknown. If mental functions are differently selected for impairment in the different forms of psychosis, then we should expect diminished coefficients of correlation among the insane, because mixing the psychoses would produce inconsistency of rank within the group. If, however, certain functions were deteriorated in all or nearly all of the insane, others remaining intact, or relatively so, this selective enfeeblement would not appear in correlation coefficients. Facts like those observed by Binet and Simon might be obscured by the methods of Hart and Spearman.

Moore, working subsequent to Hart and Spearman, limited his investigation to those cases believed by psychiatrists to be characterized by real loss of abilities, the dementias: dementia paralytica, senile dementia, and alcoholic dementia. He tested thirty demented, laborers and tradesmen, and, as controls, six young men from the same occupational group, in the following mental functions: (1) perceiving eight each (in a series) of real objects, pictures of objects, printed words, and spoken words, referring to real objects of ordinary everyday experience; (2) repeating after one exposure of the series as much of it as could be remembered without regard to sequence; (3) after a minute of mental work at calculation, repeating again what could then be remembered of the series. Moore then correlated performance within the group in each of these functions with that in each of the others. The coefficients thus resulting are interpreted as follows: "The average of all correlations of perception with the various memories is .538 That the average corre-

lation for memory and perception is as high as .538 shows that there must be a common factor present. But its presence does not exclude the existence of special forms of mental ability." Moore also correlated perceiving with remembering in the functions separately, and remembering immediately with remembering after a minute of distraction. These coefficients are positive, and mostly high, but not perfect.

The work of Moore does not seem to go beyond knowledge already obtained from study of sane persons. The coefficients do not prove that the amounts of deterioration in the functions had been equal; or even that deterioration had taken place. Moore's six sane subjects were too few to constitute a control, and are not referred to as such in treating results. Instead, Moore refers the reader to the records of subjects in preceding monographs to show that "the low values of these subjects (the insane) are distinctly pathological." This comparison is seen to be invalid, for the subjects referred to as establishing the criterion of intactness are professors and university students, almost certainly much higher in ability by original nature than the insane group.

Assuming, nevertheless, here also that the subjects really had deteriorated, the method of correlation must again be brought under criticism as ill adapted to answer questions concerning *selective* enfeeblement. A group of senile demented, all high school graduates, might, for instance, be not at all deteriorated from their original status in the mechanics of reading, but greatly deteriorated in the ability to tell what has been read. Yet correlation might result in a positive coefficient as high as that found among typical high school graduates, if the decay in repeating matter took place in proportion to the degree of ability originally present in each individual. There might be marked selective impairment, which would be hidden in coefficients of correlation.

The problem of selective enfeeblement must be investigated by computing *deviation* in various functions from a known norm or standard in each; and the person's original status in that function must be known. For such investigation senile demented would seem to be the best subjects, since in them there is natural decay of functions. It is, however, difficult to find very aged deteriorated persons, whose original status is known (known, at least, to have been generally high), and who have not some sensory or motor handicap to complicate performance, such as deafness, failing vision, or palsy.

The net result, for our purposes, of studies so far made of mental decay is not very helpful, because (1) the original status of the subjects is never known, (2) the psychoses have been mixed in experiment, without preliminary test-knowledge of the characteristics of each, if any, and (3) the method of correlation, which has been used, is not suited to show selective enfeeblement of mental functions. Every study made has suffered from one or more of these hindrances to interpretation. The information gleaned from them is much the same as that already gleaned from studies of the undeteriorated, namely, that among people (whether sane or insane) those who hold a certain rank within a group in one function tend also to hold a similar rank within that group in other functions. The question of *selective* enfeeblement of a function within a group of the insane remains unanswered. The investigators of the demented have, however, made a particular contribution in pointing the way to a new source of light. For the study of mental decay, when carried on by adequate methods, extremely difficult of attainment, is sure to throw light on the relationships among mental functions. From it we shall learn whether some functions remain intact, with impairment of other functions.

V. IS INTELLECT INHERITED AS A UNIT?

There are still other approaches to the study of the constitution of intellect. One is through the investigation of heredity. The question is whether intellect is inherited as a unit, or whether some different formula is indicated. If intellect is a unit character, subject to but one determiner in the germ-plasm, then it should act as an "all or none" capacity in its appearance among offspring of given matings. Children should be separable into distinct groups, each having a different median with respect to intellect, *i.e.* those who have intellect and those who lack it.

The methods of mental measurement teach us plainly that intellect is not inherited in this way. Instead of a broken curve, indicating a division of children into those who inherit and those who fail to inherit a unit character, we obtain the curve already demonstrated, which is continuous and symmetrical. There is but one diversified group of children, with respect to intellect — not distinct groups.

The inheritance of intellect does not, therefore, follow the simple formula of unit characters, as does the shape of peas, the color of rabbits' coats, or eye-color in man. The trait we measure and name as general intelligence is a complex, resulting from the incidence of a great number of functions, acting together in a great number of ways, yet cohering in respect to amounts found in given individuals.

Possibly each of the indefinitely numerous functions, which thus appear to act together as man's intellect, may be a unit character, inherited according to Mendel's formula. Such a possibility is at present purely speculative.

The puzzle is that a given individual should "hit," as it were, at approximately the same point in the distribution of nearly every function.

VI. CAN AN INTELLECT BE TRAINED AS A UNIT?

Studies of the learning process also give light upon the organization of capacities. The question here is as to whether training in one function spreads equally to all other functions. Is it possible to "train the mind" as a whole? Will it raise the proficiency of all performances fifty per cent, if a fifty per cent gain is achieved in Latin composition?

Numerous attempts have been made to determine the extent to which skill acquired in one performance increases skill in other performances. The conclusion which emerges from these studies is that *intellect cannot be trained as a unit*. Transfer of training from one function to other functions is far from complete. Apparently, there is spread of improvement from practice in a function only to such other functions as have elements in common with it. If two performances differ in any way, there is something in the second that remains *untrained* by the practice given to the first. If two performances differ in all respects, the second seems not to derive any benefit at all from training in the first.

To a very highly intelligent individual, nearly all situations and performances tend to have some identical elements, no doubt. To a very dull person, relatively few situations or demands present identical elements, for the dull perceive only gross similarities and differences. Thus, spread of improvement is without doubt greatest for the innately gifted, and least for the innately inferior minds. In connection with the present discussion, however, the chief point of interest is that no mind, of whatever degree of innate integrity and sensitivity, can be trained as a unit. Each function has elements special to itself, and some functions are very highly specialized, as regards the amount of transfer of training from them to others, or from others to them.

The evidence from learning, therefore, substantiates the evidence from heredity, indicating that intellect is not a unit, but a complex of many capacities, coinciding mysteriously in amount to a very marked extent in an individual.

VII. THE HIERARCHY OF ABILITIES

It has been stated that though all, or nearly all, mental functions so far measured and correlated, yield positive coefficients, all do not show an equal amount of positive correlation. Certain mental functions, for example, are shown to yield coefficients of as much as .80, for a total correlation with others of a series; while some yield coefficients as low as .10, approaching absence of relationship. To explain these facts, Spearman formulated the concept of a hierarchy of relatedness to a "general factor." Those abilities showing slight correlation with others in series of tests, were thought of as but loosely related to "general intelligence," and as constituting "special abilities." They might be displayed by persons inferior in general, or might be lacking in persons otherwise superior.

Here again, the facts are not in question. It is admitted by all that functions show different amounts of positive correlation with one another, and of total correlation with members of a series. Not all experts agree, however, with Spearman's theoretical explanation of the phenomena. Thomson has recently shown, by tossing dice of various colors, that in this game of chance (in which there is no "general factor," but only many independent factors), hierarchical order of correlation coefficients is almost sure to be obtained, for combinations resulting from throws. Thomson, therefore, holds that the theory of a "general factor," participating in all the separate performances of an individual, is not proved from

the facts about correlation coefficients. He proposes the following, regarded by him as an alternative: "The mind, in carrying out any activity such as a mental test, has two levels at which it can operate. The elements of activity at the lower level are entirely specific, but those at the higher level are such that they may come into play in different activities. Any activity is a sample of these elements. The elements are assumed to be additive like dice, and each to act on the 'all or none' principle, not being in fact further divisible."

It is not quite easy to see that this theory, finally proposed by Thomson, which might be termed the "two level" theory, is very different from Spearman's "two factor" theory, nor why the terms "higher" and "lower" should be introduced. But demonstration of the probability of obtaining a hierarchy of correlations simply from the tossing together by chance of independent factors, as with dice, adds new data for consideration. It might be that non-biological principles of probability are sufficient to explain the hierarchical order of correlations, among many tests administered to a given group, just as they are apparently sufficient to account for the particular form in which ability in any single test is distributed through the human species.

But if this is so, how account for the *consistency* with which certain abilities, like ability to draw, are repeatedly shown to correlate but slightly, while others, like completing sentences, repeatedly yield high total correlation? How account for the fact that there is marked coherence among certain groups of tests, such as "tests dealing with words only," and "tests dealing with numbers only," as contrasted with the relative lack of coherence among "tests, some dealing with number, and some with words"? It would seem that these phenomena must be at bottom *biological*. It cannot, for instance,

be demonstrated that yellow dice and red dice thrown, wherever and by whomever cast, tend always to correlate high, while green and maroon dice tend always to correlate low with each other, and with yellow and red dice. Nor can it be demonstrated that dice colored, let us say, from one end of the spectrum tend always to correlate high among themselves, but much lower with the dice colored from the other end of the spectrum, wherever and by whomever cast.

Furthermore, die-casting will not give a relationship in which throws resulting in low scores are paired with low scores, and so on, from low through high, high scores being also paired with high scores, as when organisms are tried. The correlation among throws of dice arises from *a different form of relationship*, in which the improbable throws, resulting in either very high or very low scores, are paired indifferently,¹ this indifference not being able, however, to produce zero correlation, because of the infrequency of extreme scores. The frequently occurring, mediocre scores in both series are, however, very similar, the most frequently occurring score for both being, indeed, the same. Since the mediocre scores tend to occur *both frequently and together*, because of the laws of chance, they produce positive correlations, differing in amount from series to series (also because of the laws of chance). But when organisms are tested, as has been repeatedly demonstrated, the serial relationship between two functions holds through high and low, and this, also, must be *biological*, and not explainable by laws of chance.

The demonstrations from die-casting are extremely significant, as warning us not to depend wholly for our inferences upon the amount of positive coefficients of correlation,

¹ Because of the probabilities in die-casting, every single value for red would have the same median value among the throws of yellow, which turn up in connection with it, if enough throws are made. This is not what happens in measuring mental traits. For any single value, high or low, in one function, the median of repeated measures in the other function is very different, for most traits, from the median for other values.

nor the possibility of arranging them in hierarchical order. Both of these features of apparent relationship may come of chance, within a single series. Other features of relationship must be examined in the attempt to infer biological law, especially the *consistency* with which given traits correlate to a given degree with others, when investigated by different examiners, in various groups; and the *form* of the relationship, whether all the way from highest to lowest, or only in central tendency.

VIII. PRESENT STATUS OF THE PROBLEM

Whatever may be the ultimate cause of the manifestations, educators are practically concerned with the facts. The practical implications for education of knowledge gleaned up to the present time, concerning the coherence among mental functions, have been well stated by Burt, in his recent discussion of *Mental and Scholastic Tests*: "The examiner should always discriminate between children who are backward in most subjects, and children who are backward in one subject, or limited group of subjects, alone. A child, for example, who suffers merely from a specialized disability in reading and spelling, such as so-called 'word-blindness,' is to be carefully distinguished from one who is in every respect mentally defective.

"As I have shown in memoranda previously published, educational attainments depend largely upon capacities of two kinds: first, a common or general capacity, entering into every subject in different degrees, but best exhibited in those that need thought-processes of a higher order, such as the comprehension of reading matter among young children, and, among older children, problem arithmetic and literary (or rather logical) composition; secondly, specific capabili-

ties — such as arithmetical ability, linguistic ability, manual ability, and musical ability — entering into a small group of subjects. A child who is deficient in the former will be backward in all subjects — most backward in those subjects most dependent on this central capacity (such as the subjects first named), least backward in those subjects least dependent on it (such as manual and musical subjects). A child who is deficient in one of the specific capacities alone will be backward in the limited group of implicated subjects, and in none but these.”

McCall writes as follows: “There is an objectively and practically measurable something, which constitutes the core of most aptitudes. It is overlaid with various incidental abilities, and furthered or retarded by emotional or physical characteristics of the individual. This something is general intelligence. If an individual’s intelligence is all that is known, some mistakes will be made in attempting vocational guidance, but if only one thing can be known, general intelligence is perhaps most important. . . . A pupil’s intelligence score is an approximate measure of the diameter of an approximate general ability circle, and is hence an approximate basis for vocational guidance.

“But any individual who assumes that all the spokes in an ability-wheel are of exactly equal length, or that instances of marked special aptitudes do not exist, or even that most individuals do not possess some tendency toward a special aptitude, would make as egregious an error as one who assumed that all individuals are markedly lopsided.”

These two summaries of the present status of this problem from the practical point of view, coming as they do, the one from a student of the British school, the other from a student of Thorndike, show how the two originally conflicting interpretations have been approaching middle ground. There is

found to be a quality of the individual, which results in generally superior, mediocre, or inferior performances in his case — a positive coherence in the amounts of all traits possessed, extending even to appreciable coherence between mental and physical. General intelligence is now measured, for practical purposes, as Spearman long ago predicted. Nevertheless, there are, as Thorndike maintained and maintains, mental functions, standing in which is hardly predictable from knowledge of other capacities. In rare cases there may be complete discrepancy in rank between performance in one task and performance in other tasks, with equal training. These are the cases of special talents and defects, to which this volume is devoted.

IX. MEASUREMENT OF GENERAL INTELLIGENCE: THE IQ

We now see that the “general” factor in intelligence may be defined simply as the positive coherence which exists among the multitudinous abilities of an individual, as respects their amounts. The first to obtain a quantitative measure of general intelligence, for the practical purpose of classifying school children, was Binet. Binet concluded from reflection on the research done, that failure or success in one mental function may be of slight significance for the classification of an individual, because correlation is imperfect; but that failure or success in a score of different functions must be of very great significance, because correlation among mental functions tends strongly to be highly positive. Working on this basis, he devised a large number of mental tests, intended to sample the individual’s performance in many different functions.

A mental test may be defined as a standard stimulus, which provokes a response capable of quantitative interpretation.

Binet devised numerous standard stimuli, and a method of interpreting the responses elicited, in terms of a context of scores made by children of various ages, throughout the period of immaturity. His measurements were thus in terms of "mental age," a phrase now somewhat familiar in education.

The science of mental measurement is rapidly progressing to more exact usage. The concept of "mental age" when applied to persons who vary in birthday age is in some respects misleading, and in other respects quite inapplicable (as with superior adults). General intelligence is at present usually scored in terms of points achieved, percentile attained in total distribution, or of mental ratio. The most reliable scales now available for the measurement of general intelligence in school children, score in terms of mental age and intelligence quotient (IQ). This measure (IQ) signifies the ratio borne by the intellectual level attained by a given child in tests, to the level attained by the typical child of his birthday age. For instance, a child 9 years 6 months old has an IQ of 100, if his score in tests equals that made by the average child of 9 years 6 months. If he is inferior to the average child of his age, the amount of such inferiority will be expressed by a ratio less than 100. Thus, if his performance equals only that of the average child of 5 years 2 months, his IQ will be $62 \text{ months} \div 114 \text{ months}$, or 54 (dropping fractions less than .5). On the other hand, if he is superior to the average, attaining, let us say, the performance of the average child of 14 years 0 months, his IQ will be $168 \text{ months} \div 114 \text{ months}$, or 147. An IQ of 100 may thus be thought of as "par" in general intelligence for a school child, while anything less may be thought of as "below par" to the extent indicated; and anything greater than 100 may be thought of as "above par." The IQ shows the point of focus, for amounts of per-

formance in a variety of mental functions. It derives its value for educational procedure from the positive correlation, which has been demonstrated to exist among performances in mental operations.

Scales at present available will measure general intelligence, in terms of IQ, about as low as IQ 10, and about as high as IQ 190, at certain periods of development. No doubt human intelligence ranges somewhat below and above these limits, but adequate methods of establishing the two extremes have not yet been devised. It is by no means usually realized that the range of individual differences in general ability is so wide that it is extremely difficult to invent methods of discovering its full extent. However, for practical purposes, available scales are adequate to cover the range for young school children, because intelligences that fall below IQ 25 or above IQ 175 are so rare as to be dealt with very seldom.

Within the limitations named, the general intelligence of school children can now be determined by a competent examiner, with a very small margin of error. The average error made by such an examiner will not exceed ± 5 IQ.

Not all scales for the measurement of general intelligence are scorable in terms of IQ. Some have been standardized in terms of "raw" points achieved, and some in terms of percentile status. There is at present much variety of usage in scoring, the ideal being to find *units* of measurement. It does not lie within the scope of this volume to treat the problem of establishing units for the measurement of mental traits. The general intelligence of the children to be discussed here has usually been determined in terms of IQ, which will be comprehended from the brief description given.

An ideal of students of mental measurement is to devise a scale which will measure any intelligence, from the lowest to the highest existing, after maturity, in units every one

of which is equal to every other; and to devise a scale fulfilling the same requirements for each 12-months interval of the period of immaturity. This ideal is far from being realized at the present time, but the future will see it achieved.

In the meantime scales for the measurement of special talents, which are not measured by the scales for measuring general ability, are being worked out. What these special talents are we shall now consider.

X. THE MEASUREMENT OF SPECIAL ABILITY

Although much further research is required before we can identify all the mental functions which are incoherent with general intelligence, we already have some knowledge of the matter, useful for the welfare of school children. Certain abilities are shown repeatedly by different investigators to be relatively independent. Success in music and in representative drawing is very slightly correlated with success in other school subjects. Spelling is far from perfectly predictable from grades in schooling generally. Mechanics is relatively independent. Whereas ability in reading and in arithmetic is highly, but not perfectly, correlated with general competence.

These facts mean that from knowledge of a pupil's general intelligence we can make very reliable predictions as to his capacity for reading and for arithmetic, somewhat less reliable predictions as to his aptitude for spelling or mechanics, and that our predictions concerning his ability to draw, sing, or play musical instruments should be given without confidence in their reliability, if given at all.

Other kinds of performances, like the management of people, appreciation of a joke, dancing, the management of wild or domestic animals, have not been thoroughly studied

in their relation to general intelligence, though these and scores of others which will occur to the reader, might be of great significance for practical psychology, if shown to be somewhat independent talents.

As we have already said, most of the functions performed by human beings are very complex, and capable of analysis. To read, understand, and execute a page of any musical composition is a very complicated performance. The attempt to measure special ability has been the attempt first to scale total performance in the function, and second to scale performance in the various coördinating functions contributing to total result. Thus in the case of musical talent, Seashore has found by analysis a large number of contributing factors, and has actually devised scales of measurement for five of these subsidiary functions.

Measurement more or less adequate can now be made of ability to read, spell, draw, write, put mechanical contrivances together, and calculate. This list does not by any means exhaust the possibilities of measurement in particular functions at present, but exemplifies them. Slowly we are approaching the point of being in position to tell not only how a child stands in general intelligence, but also to indicate his status in regard to special abilities. The "picture" of the total relationship among a person's abilities is called a psychograph.

XI. THE PSYCHOGRAPHIC PICTURE OF INDIVIDUALITY

A psychograph may consist merely of numerical statements of the individual's standing in various mental capacities respectively; or it may be presented in the form of a graph drawn from the figures. No standard graph has been agreed upon. Sometimes the method is to present points of deviation from a horizontal line representing the typical performance;

sometimes to present the deviations from a vertical line, representing the typical; sometimes to present deviations along the spokes of a "wheel," the typical being taken as a circumference drawn midway between the center and the perimeter of the circle.

Figure 3 is an illustration of the first mentioned mode of presentation. It shows the status of a school boy in various

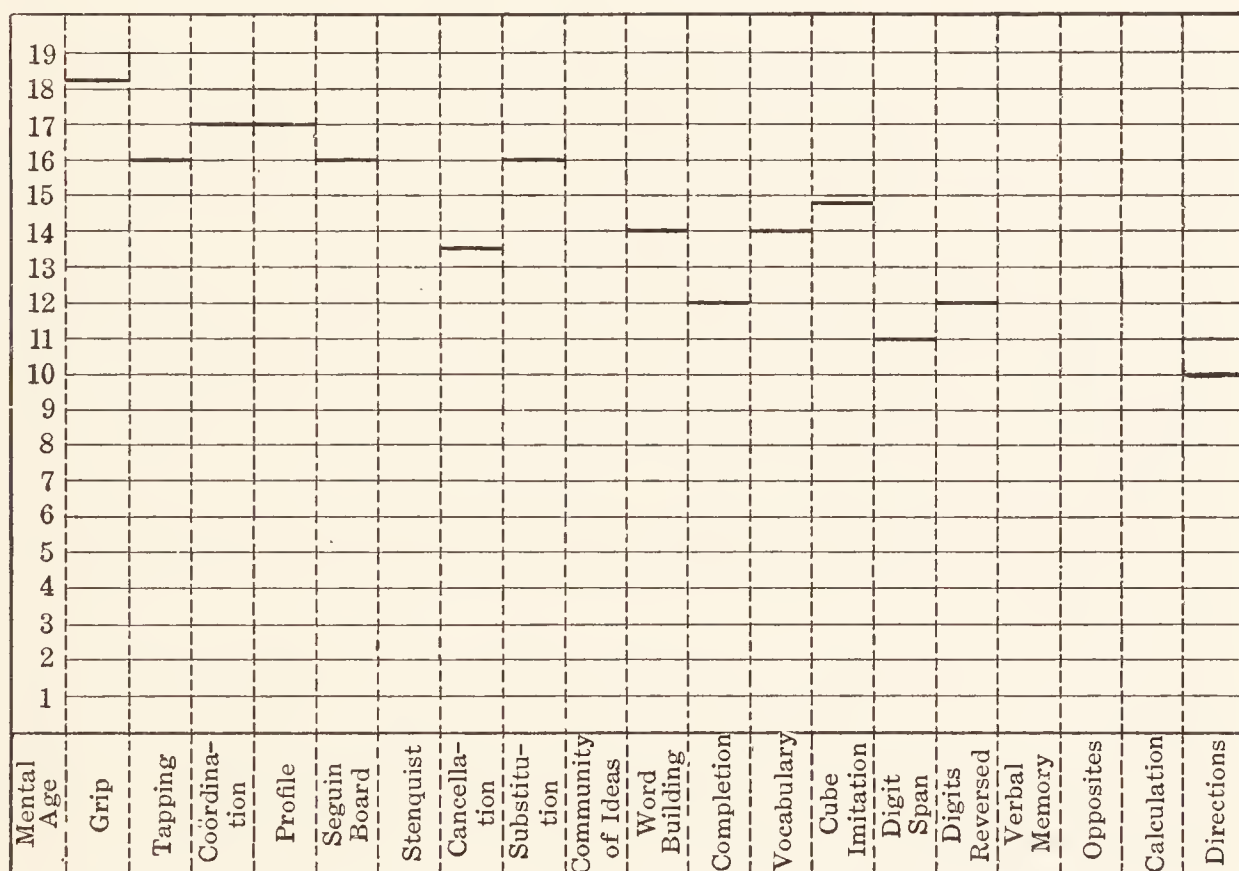


FIG. 3. — The psychograph of a school boy, showing his standing in various mental functions; illustrating use of the horizontal line to denote typical performance. The scores are in terms of mental age. (From Hollingworth's *Judging Human Character*. Reproduced by courtesy of D. Appleton and Company.)

mental functions measured. This boy is 18 years old. In interpreting the psychograph, which is platted in terms of mental age, it must be borne in mind that many of the capacities here included are matured by the age of 16 years. The individual is not, therefore, subnormal with regard to them. This case illustrates some of the difficulties of treating adolescents and adults in terms of mental age.

Figure 4 shows the use of the vertical line as the “type” or “norm,” picturing the extent to which the individual meas-

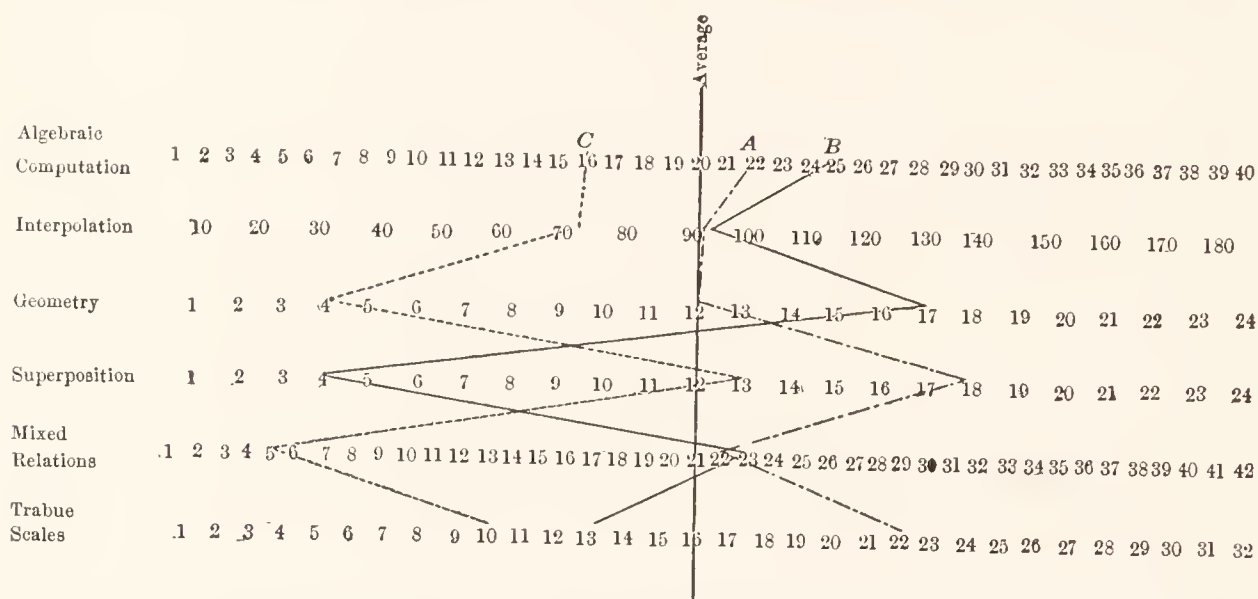


FIG. 4. — The psychographs of three school girls, showing their standings in various mental functions, measured to determine mathematical ability; illustrating use of the vertical line to denote typical performance. The scores are in terms of weighted deviations. Scores to the right are above, and scores to the left are below, average. (From *Tests of Mathematical Ability and Their Prognostic Value*. Reproduced by courtesy of Agnes L. Rogers.)

ured departs from or corresponds to the typical, in the functions tested.

Figure 5 illustrates the use of the circle, with radii to show standing in the various mental functions. The adolescent presented is near the typical (the 50 percentile) in nearly all functions measured.

Which of these forms of graph is best adapted to its purpose has not been determined. All are simply different methods of picturing the same facts.

The chief obstacle to the platting of psychographs, for such capacities as are now measurable, is that scales for measurement have been standardized in different terms. To plat a lucid psychograph, some traits on which have been measured in P.E., some in IQ, some in percentiles, some in “raw” points, some in values of a T Scale, some in terms of school grade achieved¹ is now impossible, because of the difficulties of

¹ For explanation of technical terms see McCall's *How to Measure in Education*.

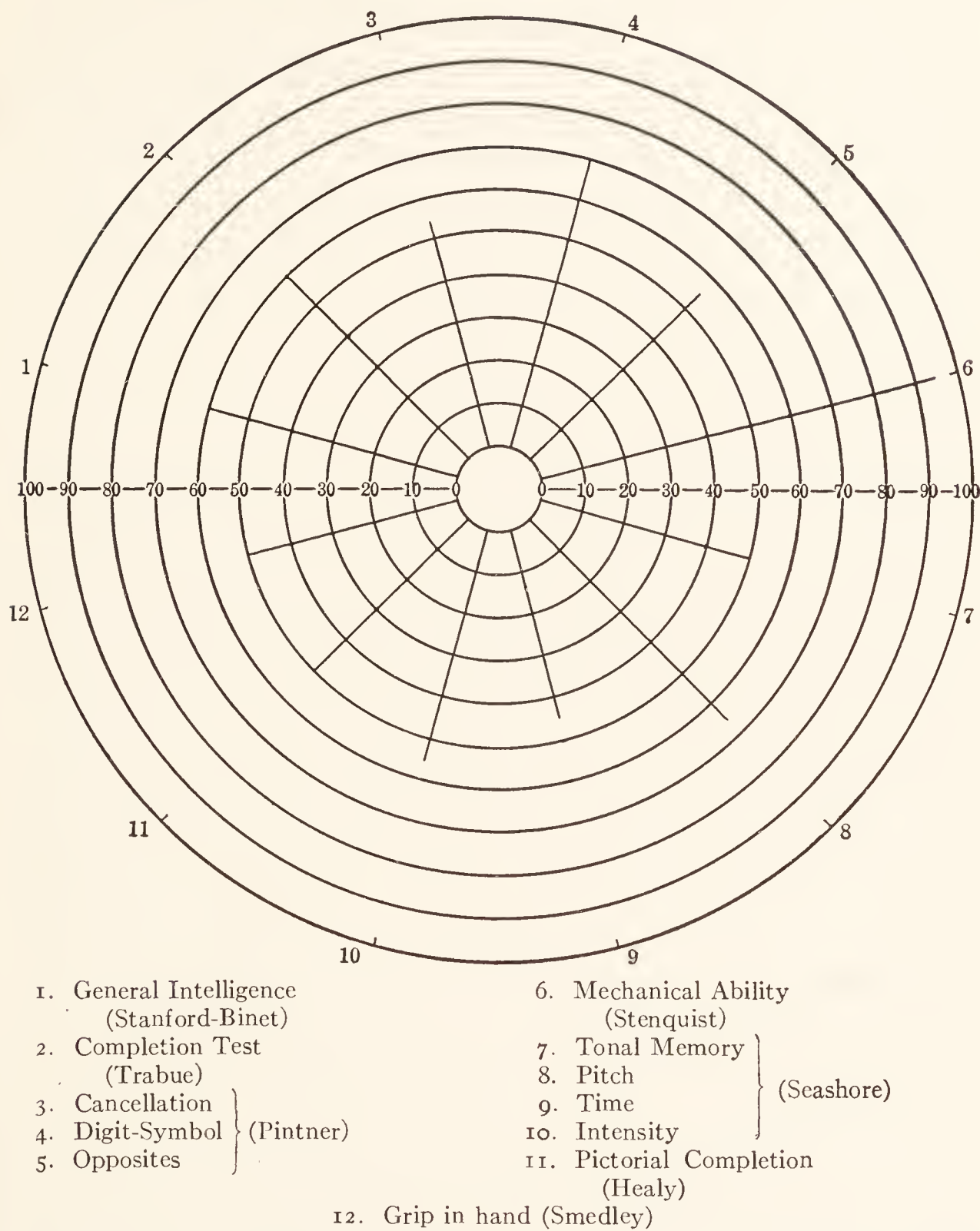


FIG. 5. — The psychograph of a school boy, showing his standing in various mental functions; illustrating use of the circle as a diagram, the median circumference denoting the performance of typical persons of his age. The scores are in terms of percentiles.

equating all these “steps” of difference. The psychographs here presented will, therefore, be understood to be crude, merely approximating the lucidity of those which will be

made in future, when the science of mental measurement has made greater progress. Each of the methods of standardization has some advantages and some disadvantages, as compared with the others. Only experience and discussion can finally determine which is best. It is desirable to achieve uniformity as soon as possible, in order that the psychographic study of individuals may be facilitated.

XII. AT WHAT AGE IS MENTAL ENDOWMENT EVIDENT?

The question arises as to when special talents and deficiencies become evident in growing individuals. We know almost beyond any doubt that the degree of general intelligence is manifested from the beginning of life, and could be measured then if our instruments of precision were fine enough. With present methods we cannot undertake with confidence the measurement of general intelligence much before school age. Extreme deviations may be reliably identified as early as 3 years of age, or earlier, but slight amounts of deviation cannot be reliably determined by available methods before the age of 5 or 6. The inadequacy of method with very young children arises, partly because it is so difficult to obtain non-select children under school age for purposes of standardization, partly because of the coarseness of the "steps" at present used to measure. The most refined and reliable scales we have are cast in terms of "mental age," and some do not allow for any difference of less than "2 months of mental age." An error of only two misscorings in the same direction would therefore result in a considerable error in the IQ of a child 3 years old; since 4 months is a large percentage of 36 months.

As early as 6 years, however, even by present methods, we can determine objectively the individual's status in gen-

eral intelligence. The indications are that when the measurement of special talents has made similar progress, we shall find that these become evident just as early as general ability does. These special talents are gifts, innate in the organism, and manifested no doubt from the beginning of life, just as general intelligence is.

In the discussion of special gifts for music, drawing, and calculation we shall see that investigators have been particularly struck by the very early age at which these were manifested in the persons studied. It is common for those who later became historical prodigies in these performances to have shown symptoms of their ability as early as 3 or 4 years of age.

On the other hand, special deficiencies in these functions are not commonly noted until after school has been entered, usually long after. This is inevitable, because no one is likely to suspect a child of tone-deafness, for instance, until his music teacher has worked with him for some time. But conspicuous aptitude for melody and rhythm is likely to be noticed.

The question arises: Can these special talents be acquired, or the special deficiencies be overcome, by any course of training? Scientific psychology tends more and more strongly to the conclusion that psychology and education can do nothing to alter the amounts or relationships of innate mental endowment. They can but measure endowment and give it training suited to its requirements. The history of Seguin's form-board seems to illustrate the evolution of the point of view on this question. About sixty years ago this form-board was hopefully used as a supposed *means of altering* original endowment. Feeble-minded children were given exercises in placing and replacing the blocks in it, in order that they might become more intelligent. To-day this form-

board is used as a *means of gauging* original endowment. Psychology cannot create endowment; it can merely measure and describe it. Education cannot bestow mental gifts; it can only utilize such as are innately present within the organism. Talent and genius can be created in children only by the procreation of parents, who are the biological carriers of extraordinary endowment.

XIII. THE FREQUENCY OF MARKED SPECIAL TALENTS AND DEFECTS

No census of special talents or defects of given degree has ever been taken. Surveys have been made showing the distribution of musical sensitivity, of ability in drawing, spelling, calculation, and so forth. These distributions tell us the frequency of extreme deviations in these functions, but they do not tell us to what extent the deviations are *special*. From them we cannot learn whether or not the extremely fortunate deviations are identified with great general superiority, and whether the unfortunate deviations represent the work of generally stupid children. What we require is a survey of children of uniform age, educational opportunity, and IQ, in respect to music, drawing, spelling, and so forth.

Although we cannot state with precision the frequency with which marked special gifts occur among the stupid, or marked special deficiencies occur among the highly intelligent, we know that such cases are quite rare. It is necessary to remind ourselves constantly of this fact, because it would gratify the demand for justice and fair play to find that special gifts are freely distributed among the generally inferior, and special defects frequently found among the superior. The truth which satisfies our desires need be stated but once, to be apprehended and remembered. The truth which offends

kindliness, self-interest, or cherished beliefs, and is hence unsatisfying, requires emphasis. Therefore we must take particular care to bear in mind throughout the whole of our discussion of special talents and defects, that we are dealing with comparatively rare phenomena. The distribution of abilities, as determined by biological law, does not correspond to our concept of fair play. Nearly all stupid persons are inferior in all capacities. The great majority of gifted persons are superior in nearly all their abilities. The majority of human beings are neither markedly inferior nor markedly superior, but are "typical" (not far from the median or average) in all respects.

XIV. POSSIBLE ORIGIN OF THE DISSOCIATION OF CERTAIN CAPACITIES

Why should certain capacities, like musical sensitivity and ability in representative drawing, be so loosely correlated with general ability, throughout the species? Why should other capacities, like ability to name opposites and to complete sentences, give such high and positive total correlation? We do not know with assurance the answers to these questions. Perhaps the evolutionary explanation is adequate. Those variants lived to transmit their hereditary constitution, whose functions were so correlated that life was well sustained. Perhaps functions are, therefore, loosely correlated, where nothing would be added to the probability of survival by high correlation.

It makes little difference in a world like ours whether an intelligent man can or cannot sing. It is of small moment whether one who can easily detect absurdities of statement can also produce fine representative drawings. It is very important for survival, on the other hand, whether one who

can detect similarities can also detect differences, in the objects which surround him, and whether he can at the same time anticipate incomplete meanings in the sentences and gestures of those whom he meets.

The suggestion also arises as to whether those performances which do not cohere closely with performances in general are such as involve the sensori-motor apparatus to a special degree, as distinguished from the central nervous system. Those functions which depend relatively little upon equipment of eye, ear, or hand, but essentially upon the sensitivity and integrity of the cortical neurones, might be expected to cohere closely, constituting what we should properly call intelligence. Where performance depends largely on sense organs and muscles, the correlation with functions largely independent of sensori-motor apparatus might be expected to be only as great as the tendency to general organic quality would bring about. Certainly drawing, music, and mechanical ability, for example, involve eye, ear, and muscle to a much greater extent than does the detection of absurdities in life situations, or the learning of symbolic significances. The mechanical technique of reading clearly involves the sensori-motor apparatus to a much greater extent than does the comprehension of what is read.

It would be valuable to determine to what extent a hierarchy of correlations would be consistently maintained in the use of tests, selected for graduated degrees of involvement of equipment accessory to the central nervous system.¹

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¹ This suggestion originated with a colleague of the present writer, who is working upon allied problems.

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CHAPTER III

CONSIDERATION OF THE NEURAL BASIS

I. THE PHYSIOLOGICAL MECHANISM OF MENTAL LIFE

PSYCHOLOGISTS no longer question that the product of mind, which we call behavior, by which mind is judged, is in some way intimately connected with the sensitivity and integrity of the nervous system. The proof of this has often been set forth, and will merely be taken for granted here. Any organ or substance which reacts upon this sensitivity or integrity may then indirectly influence mental life in certain respects. For instance, the glandular system of the body, especially that part of it which comprises the glands of internal secretion, may affect behavior by affecting the growth or function of the nervous system. Drugs may influence mental processes, because they act upon the neurones. However, all present knowledge points to the conclusion that if the nervous tissue could be isolated from such influences, mental life would be immune from their effects. Mental life is but indirectly subject to such influences, in so far as nervous tissue is affected in a particular manner by them.

II. ATTEMPTED LOCALIZATION OF MENTAL FUNCTIONS

When it was thought that such supposed entities as "the reason," "the will," "the memory," and "the imagination" would be identified as mental functions, it was also supposed that a definite location for each might be found in the brain. As investigators were compelled to change their concept of a

mental function, and to define mental functions in terms of observable performance, they still sought to discover whether or not each performance might be referred to a definite set of neurones. This question of brain localization constitutes a current topic of research. So little information can be given as yet upon the subject that it is, perhaps, unwarranted to consider it at all in this volume, where the chief interest does not center in the controverted theories of neurology.

Much of the proof for the statement first made in this chapter, that the nervous system is the physiological mechanism of mental life, has been adduced through study of neuropathology. Persons impaired in a given manner in their nervous tissue, show behavior characteristically altered. Moreover, given alterations in behavior can be produced experimentally in animals, by altering the connections in the nervous system, and by no other means. Through these observations it has been possible to assign certain functions to parts of the physiological mechanism.

In the case of man, both by observation and experiment, "the nervous structure below the hemispheres of the cerebrum has been excluded from the possibility of acting as the immediate physical basis of mental states."¹ The higher mental processes, which involve the possibility of speaking, calculating, and responding by learned reactions to complex situations, have their correlate in the cortex (the agglomeration of neurones in the cerebral hemispheres). Physiological psychologists therefore investigate the cortex, in their search for the particular neurone-patterns or areas involved in particular intellectual performances.

The problems of brain localization have, therefore, been approached through the study of the alterations in performance, which accompany alterations in given areas of the cor-

¹ See Reference to Ladd and Woodworth.

tex. Alterations in restricted areas of brain tissue, in human beings, are brought about chiefly by obstruction of a blood vessel, hemorrhage, tumor, and laceration or depression through injury to the skull.

One of the early observations, bearing upon topics considered in the subsequent chapters of this volume, was that by Broca. Broca described two cases of pathological impairment in a limited convolutional region of the left cerebral hemisphere, in which the use of words was lost, without loss of intelligence as expressed in other ways. Broca therefore suggested "articulate language" to be a function connected with the part of the brain to which the impairment had been restricted.

A large number of similar observations have been reported since Broca's publication, describing cases of selective loss of some linguistic function, especially in connection with paralysis of limbs. The localization of articulate language, as a special ability, in Broca's area, is still, however, debated by those most competent to discuss the matter, and no positive statement is at present warranted. Head, one of the foremost among modern students of neurology, has recently advanced the theory that special disturbances of articulate language (aphasia, alexia, agraphia, aphemia) are due to disturbances of those psychic processes whereby *symbolic association* is accomplished, — whereby men learn to imbue symbols with meaning. Von Monakow interpreted the array of data existing in 1914 to show that all gnostic functions (intellectual performances) pertain to the cortex as a whole, and not to any center or centers in the brain. He held that no case of aphasia permanently remains, unless there is at the same time diffuse cortical degeneration. Ladd and Woodworth, writing in 1911, concluded that "there is good evidence that the Broca region is the most vulnerable part of

the cortex, as regards the motor coördination of speech," but that "the entire cerebrum would seem to be, of necessity, involved in man's linguistic attainments and uses."

III. THEORY OF CONGENITAL LESION OR ATROPHY CRITICIZED

Reasoning from analogy with cases where a function of language is lost selectively, through organic disease or impairment of brain structure, it was thought by those who first described innate special disabilities, as in reading or spelling, that such defects must be due to congenital brain lesions or atrophies. Neurological research has never verified this supposition. No cases showing innate disability to be correlated with any peculiarities of restricted areas in the cortex have ever been recorded. Tilney and Riley, summarizing critically the data of neurology in 1921, cite no cases considered to afford authentic evidence of localized lesions or defects, as the basis of congenital difficulty in reading, spelling, music, or other functions with which the present treatise is concerned.

The theory of innate lesion or atrophy of a cortical area, to account for disability in a special mental function, seems unscientific for other reasons, aside from the fact that it has never been objectively verified by actual observation of a structural defect. One of these reasons is that a theory, formulated to take care of the neural basis of specialized disabilities, must take care of specialized gifts, as well. Cases where a generally stupid child is innately gifted with special ability to master the mechanics of reading, for example, are no doubt as frequent as cases where a generally capable child learns them with difficulty. The theory of specialized lesions or other faults of structure might cover disabilities, but would it cover special talents as well?

Still another consideration prevents us from regarding the theory of localized brain defects as masterly. This is the fact referred to in our preliminary discussion, that every single mental function, which yields to measurement, is found to be distributed among human beings according to a probability curve. (See Figure 1, page 8.) The functions which we herein consider are not exceptions to this principle. Performance in reading, spelling, arithmetic, drawing, music, and so forth, shows children or adults, chosen at random, to be distributed in the given form. Those who have exceptional talents or defects in the function fall within the *symmetrical surface* of this curve, at its opposite extremes. Nowhere is there a point of demarkation, denoting absolute lack of the trait in a group falling below that point, as there would be if a number of individuals suffering from lesions were introduced into the distribution. We may fairly demand of a theory which undertakes the explanation of the most extreme deviations, the explanation of the deviations of lesser magnitude, as well. The curve obtained by test approximates that form which mathematicians tell us appears when an infinite number of factors act together in an infinite number of ways, the extreme deviations occurring inevitably, by chance. A theory introducing the adventitious circumstance of lesion or atrophy is thus superfluous to the explanation of the extreme unfortunate deviations. To admit it would violate the rule of scientific method known as the law of parsimony, for we do not need it in order to explain the facts.

IV. RESTITUTION OF FUNCTION WITHOUT REGENERATION OF STRUCTURE IN INJURED BRAINS

Fully as important as any of the facts mentioned above, for criticism of the theory that special deficiencies are due to localized defects in brain structure, are the experiments with

reëducation of those who have suffered *loss* of an ability. Persons who have lost the power to read, or write, or speak after destruction of brain tissue, may learn to perform these functions again, without regeneration of the area impaired.

If the neurones destroyed, and no others, were the special mechanisms rendering possible the functions lost, how would restitution of function be possible, without repair of the destroyed tissues?

V. ATTEMPTS TO ESTABLISH A NEURAL BASIS FOR THE "TWO FACTOR THEORY" AND "THE TWO LEVEL THEORY"

In prosecuting their researches from the psychological point of view, by the method of testing *performance*, Spearman, Moore, Thomson, and other investigators referred to in the preceding chapter, did not neglect the attempt to reconcile their findings with a possible neural basis.

Spearman wrote: "The theory of 'two factors' just delineated, though primarily of psychological origin, has shown itself capable of translation into terms of cerebral physiology." The "specific factors" Spearman would identify with some "particular cortical region, or other neural characteristic, coördinated to the particular performance in question." The "general factor" is derived from the fact that all neurones of the cortex arise from the same heredity, and must resemble each other, as "the hair in one region of a person's scalp normally resembles that on the other regions" (a somewhat precarious analogy); also, from the fact that all parts of the brain are nourished by the same blood supply; and from the supposition that "each momentary focus of cortical activity receives continual support from energy liberated by the entire cortex (or some still wider neural area)."

Thomson said: "Let us suppose that the mind, in carrying out any activity such as a mental test, has two levels at which

it can operate. The elements of activity at the lower level are entirely specific ; but those at the higher level are such that they may come into play in more than one kind of activity, in more than one mental test. . . . The difference between the levels may be physiological, as between cortex and spinal cord, or it may be the difference between conscious and non-conscious, or what not. The theory may later be reduced to a less harsh dichotomy and there may be gradations from the one level to the other."

These attempts to find a neural basis for the "Two Factor Theory" and the "Two Level Theory" are obviously not very complete.

VI. PRESENT STATUS OF THE PROBLEM

The conclusion is that at present experimental neurology has nothing secure to offer by way of establishing the neural basis of the special talents and defects, which we wish to consider. We must suppose that in some way unknown they are connected with neural activity, but localization of each function in a restricted area of the brain structure has never been established.

The deviations in performance are almost certainly biological, and not pathological. Each mental function is by original nature possible in some degree to every person, the degrees of potentiality being of enormous range, and distributed among members of the species according to a frequency curve. The form of this curve indicates that the determinants of aptitude are approximately infinite in possibility of combination. The extremes of deviation from the *typical result* of these determinants acting together, are, as stated, very widely separated, as in any game of chance combining many factors, but they nevertheless have limits, which are knowable. The determinants exist chiefly (perhaps

exclusively) in the germ-plasm, from which human organisms spring, and which carries inheritance from countless combinations of ancestry for persons now alive. It is neither necessary nor plausible to introduce a theory of brain lesion or atrophy to explain the extreme minus deviations, leaving the equally extreme plus deviations thus unexplained.

The sum total of a child's standings on these curves, in the multitude of mental functions which are possible to human beings, constitutes his psychograph or *mentality*. The physiological aspects of this inheritance may ultimately be found in brain chemistry, or in the discovery of some principle of physics at present unknown. It may be an inheritance of function, rather than of structure. We do not know.

The present status of the problems indicated in this chapter may be recapitulated in the words of Ladd and Woodworth: "The analysis of mental functions into their elements, in a manner suitable for physiological use, has scarcely been begun."

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CHAPTER IV

READING

I. RELATION BETWEEN IQ AND CAPACITY FOR READING

It has been stated that most of the mental functions, which human beings perform, are not elementary, but are capable of analysis into many contributing factors. Reading has been shown by such analysis to be a very complex function, interference in any part of which may result in disability. The causes of failure to learn to read under instruction, therefore, differ from child to child. Huey, who spent years studying the psychology of reading, finally became so imbued with the wonder of the process, that he felt that to know it in all its aspects and ramifications would be to know all psychology.

Correlations between IQ and reading ability, among children of the same age, in both silent and oral reading, are positive and very high. This is especially true of reading for the understanding of sentences. Correlation between general intelligence, as measured by a scale like Stanford-Binet, and reading ability, as measured by a scale like Trabue's Language Completion, or Thorndike-McCall's scale for understanding of sentences, reaches as high as .90, and hardly ever in any group falls below .60.

These correlations indicate that general mental maturity is very closely related to learning to read. The very intelligent children are the best readers in by far the majority of cases, while school children who do not learn to read under ordinary instruction, are usually feeble-minded. On the basis

of experimentation in this field, Ranschburg suggests that even so mechanical an aspect of reading as ability to call correctly words exposed in a tachistoscope, may serve as a rough means of separating feeble-minded school children from the others. Nevertheless, even with correlation coefficients reaching as high as .90, there may occur occasional cases of very marked discrepancy between general intelligence and ability to read.

Very early reading, with little or no formal instruction, is often found among children of very high IQ. Of four children measuring over 180 IQ (Stanford-Binet), found by the present writer in New York City, every one learned to read simple matter fluently during or before the third year of life. Their early mastery of reading was but a symptom of their great general capacity.

Just what degree of intellectual development is typically reached before children can be taught to read is not known, but it is probably not far from a 6-year level. That is, children of ordinary intelligence can learn to read after they have passed their sixth birthday. A child who can read fluently at a mental age much below this must be considered to show a special ability; while one who cannot begin to learn at or above this general level¹ is afflicted with a special defect, in some of the functions which enter into the reading process. These functions may be classified as those which enter into *mechanics*, and those which enter into *comprehension*, of reading.

II. THE MECHANICS OF READING

Under the mechanics of the process fall the *sensory*, *motor*, and to a great extent the *perceptual*, elements in reading.

The sensory elements include the participation of eye, ear,

¹ It must be remembered that children and adults of almost any birthday age may be at this general intelligence level.

and muscles as sense organs, furnishing respectively the visual, auditory, and kinæsthetic contributions to the total function. In the case of the blind, tactual sensations replace the visual, and in the deaf, the visual replace the auditory. Sensory impairment, that is, impairment of eye, ear, or muscle as an organ, may prevent an intelligent child from learning to read. Examination of the special senses is the first step dictated by common sense and scientific procedure, when an intelligent child does not learn to read. In this way it has happened historically that the first cases of special disability in reading and spelling among school children have been reported by ophthalmologists, to whom they were taken for examination of the eyes. Parents naturally sought the expert who knows eyes in such cases, for to one who has not studied the psychology of reading, it appears that a person "reads with his eyes" only.

The *visual defects* which may most commonly interfere with the mastery of the mechanics of reading are myopia, hyperopia, astigmatism, cataract, muscle-weakness, diplopia, and anomalies of the retina. Surveys of school children by competent oculists have shown that considerable numbers suffer from eye-defects sufficient to cause difficulty.

Deafness obviously may constitute an interference, since the correct sound of the word is essential to reading. Not so obvious is the rôle of the *kinæsthetic sensations*, but we are led to believe that their part is important through the studies of Fernald, later to be reported here.

Under the motor elements involved, we have to consider *articulation, pronunciation, eye-movements*, and the *coördination of arm, hand, and fingers* in writing words. It is hard for an expert reader, like an educated adult, to realize without first-hand study of the facts, to what extent these elements originally entered into his learning. The inexperienced

reader tends to retain lip-movements, and, indeed, movements of the whole apparatus of articulation, in silent reading.

Perception of a stimulus may be defined for our purposes as seeing, hearing, or otherwise interpreting it in a certain way. Perception is habit, learned just as other habits are learned. We perceive the spoken words "home again" as such, because we learned to do so. One who has not learned, will not perceive two words, but only a jumble of articulate sound. In reading, the *perceptual elements* include the formulation of habits of responding to parts, and to groups of words, as such. Many investigations have been made of the perceptual elements in the mechanics of reading within the past twenty years.

It has been discovered that the word may be learned without first learning the separate letters which compose it. Spelling and reading are thus psychologically far from identical. In perceiving a word, all parts are not equally stressed. The first half and the upper half of the word have a great advantage over the last and lower halves. In fluent reading, the eye moves by jerks across the line, making three to five pauses in crossing an ordinary page of printed matter. Oral reading requires about 1.6 more pauses per line than silent reading, and the average duration of these pauses is longer. Thus oral reading requires 44 to 64 per cent more perception time than does silent reading. The unit of perception in reading may be the letter, the word, the phrase, the sentence, or even the paragraph, according to the training of the pupil, the degree of skill attained, and the extent to which he "skims." The letter or the word as the unit of perception results in halting and expressionless oral reading, and in retarded silent reading.

These are some of the results of fundamental studies in the psychology of reading, which help us to understand cases of

individual difficulty. Recently Gates has made intensive study of reading and spelling by the methods of correlation, with special reference to disability. He finds that partial and multiple correlations reveal an ability or abilities common to all perceptual tests involving *words* as materials, sufficient to cause fairly high correlations between them, as compared with the correlations between these tests and tests not involving words. By hypothesis, this common factor is defined as an ability to perceive clearly the significant details of words. The multiple correlations of these tests with spelling are higher than with reading, and it is suggested that those who have a very favorable form of word-perception are to some extent learning (or relearning) to spell during the course of ordinary reading. Gates also points out that poor reading is not caused by bad habits of eye-movement, but on the contrary, faulty eye-movements are merely symptomatic of the fact that the child cannot read well. Not having mastered the mechanics of reading, his eyes move hither and yon at random, seeking, by trial and error methods, to get at the matter before him. Wrong eye-movements can be cured by teaching the child how to read. The child cannot be taught to read by correcting his eye-movements.

It should be added, finally, that all the functions referred to above, and possibly others that analysis has not yet made evident, must be synthesized in an automatic set of habits before the child becomes proficient in the mechanics of reading.

III. COMPREHENSION IN READING

The elements of reading thus far considered are those that contribute to mechanics. Reading to recognize forms and to pronounce words is to be distinguished psychologically and pedagogically from reading for the *understanding* of sen-

tences. Every teacher of much experience in the elementary school will be able to recall children who could read fluently from the printed page, but could not tell what they had read, nor answer questions about the context. In reading to grasp meaning, additional processes, more difficult to perform, are involved, beyond those required to "see and say" the words.

As would be expected, the ability to master the mechanics of reading is more loosely correlated with general intelligence than is ability to *comprehend* the matter read. The comprehension of meaning is a very large factor in intelligence. It might almost be maintained that intelligence *is* grasp of meaning. A child who has perfected the mechanics of reading, understands what is read in accordance with his general intelligence, as correlations prove.

Gates has shown that even in the case of children who are quite deficient in oral reading, the correspondence between general intelligence and comprehension of the context in silent reading, as revealed in answers to questions about the material read, is very much higher than would be believed probable. Such a child, using his lame mechanics, draws meaning from fragments, in accordance with his general intelligence.

On the other hand, young children are sometimes found, who have become very fluent in mechanical reading, who can thus read very abstruse matter, without getting any meaning from what they read, because of the limitations of general intellectual development.

As a result of his studies of "Reading as Reasoning," Thorndike observes: "Reading may be wrong or inadequate (1) because of wrong connection with words singly, (2) because of over-potency or under-potency of elements, (3) because of failure to treat the ideas produced by the reading as provisional and to inspect, and welcome or reject them."

This third cause of inferior reading is found invariably in children of low IQ, for to read in this way, understandingly, involves the weighing of many elements in a sentence, their organization in the proper relations to one another, and the selection and rejection of connotations — all functions of general intelligence. It is by tests of such functions that IQ is determined. Therefore, it is not surprising that comprehension in reading is so highly correlated with IQ, among school children of the same age. It is between IQ and mechanical ability to read words, that marked discrepancies may occasionally exist, as illustrative cases show.

IV. WORD BLINDNESS

As has been stated, the first cases of inferiority in reading were reported by ophthalmologists, who, upon discovering nothing wrong with the visual apparatus of the child brought for examination, pronounced the difficulty to be word blindness or “congenital alexia.” In using these terms, they reasoned from analogy with pathological cases of selective loss of function in adults, referred to by us in Chapter III.

The first cases reported from this point of view were, so far as the present writer can determine, those of Kerr and those of Morgan, both reporting in 1896. After these, a number of individual cases were reported in France, England, Germany, and the United States. In 1915, Schröck and Clemesha respectively summarized all literature to that date, the former presenting a bibliography of thirty-two titles. The great drawback to clear interpretation of these cases is that general intelligence was not measured. Some, at least, of the children were feeble-minded, for we find cited as evidence of good general endowment, performances which we now know to be typical of children much younger than those being described.

Hinshelwood, an ophthalmologist, published in 1917 a general discussion of non-readers, from the medical standpoint. According to his treatment of the subject, non-readers constitute a group apart, defined by some congenital,¹ pathological defect in brain structure, but for which they would have read normally. This concept is directly derived from analogy with cases of *lost* function in diseased persons.

“By the term congenital word blindness, we mean a congenital defect occurring in children with otherwise normal and undamaged brains characterized by a difficulty in learning to read so great that it is manifestly due to a pathological condition, and where the attempts to teach the child by the ordinary methods have completely failed. . . . The recognition of this condition was the direct outcome and result of the previously acquired knowledge of those symptoms of cerebral disease, which we have been studying. . . . No doubt it is a comparatively common thing to find some who lag considerably behind their fellows, because of their slowness and difficulty in acquiring their visual word memories, but I regard these slight defects as only physiological variations, and not to be regarded as pathological conditions. It becomes a source of confusion to apply to such cases, as has been done of late, the term congenital word blindness, which should be reserved for the really grave degrees of this defect, which manifestly are the result of a pathological condition of the visual memory center, and which have proved refractory to all the ordinary methods of school instruction.”

This is the supposition which was critically considered in Chapter III, and shown to be irreconcilable with facts known to psychology. Hinshelwood did not make mental examinations of the cases which he describes, by standard psychological methods. He did, however, work out by experience a method of teaching, whereby all the non-reading children

described learned to read. This consists simply in returning to the primitive method of instruction, beginning with the letters of the alphabet as units of perception, and proceeding by teaching the spelling of words. The necessity of individual teaching is insisted upon.

Aside from the improbabilities of neurological theory, this work is a valuable contribution to the study of children who have special difficulty in reading. It calls attention to the needs of such children, and shows that they can be taught.

V. PSYCHOLOGICAL STUDIES OF SPECIAL DEFECT IN READING

In 1917 Bronner published several interesting cases of special backwardness in reading, studied by the methods of psychological analysis. Bronner states that deficiency in reading, in children of normal sensory capacity and intelligence, sometimes is related to special deficiencies in making visual associations or auditory associations. In the former case the visual details of the word would be elusive. In the latter case, the phonetic elements would be inadequately heeded. Since ordinary success in reading arises through both these avenues of approach, deficiency in either might result in poor reading. Bronner suggests that the avenue which is most approachable in these cases be specially utilized. All children cannot easily learn to read by the method which serves the majority. Bronner does not give results of experimental teaching in the cases analyzed.

In 1918 Schmitt reported thirteen cases from the Chicago Schools, with many details of mental and physical examination. Unfortunately, systematic standard tests of general intelligence were not given, which must be considered a defect in the study, since exact comparisons of reading deficiency

and mental age, or IQ, cannot be made. We have the investigator's assurance that "sufficient tests were given to establish normal intelligence."

The conclusion that special deficiency in reading ability was present, was made upon the following criteria: (1) regular school attendance; (2) reasonably good health and physical condition; (3) no sign of visual defect; (4) persisting slowness in learning to read, or total inability manifested over one or more years of school life; (5) general mental ability good or average; (6) no other interfering factor, such as foreign language in the home, dislike of school, abnormal unresponsiveness to school, or other social situations. Where all these conditions were satisfactorily met, central deficiency in capacity for learning to read was assumed to characterize the child.

It was then found that many of the thirteen thus selected had particular difficulty with phonetics — could not readily connect the sounds of letters with the visual symbol. They could all match words. All could point out the difference in two words differing in one letter. Those who were old enough to have learned to write could transpose a page of print into script. These facts are taken as evidence that the difficulty must be central and not sensory.

Four of the children were followed up with teaching in a special class. Phonics were taught. The easiest letters — those that can be prolonged — were taught first (r, f, l, m, s). In the effort to make the work interesting, the phonics were presented in a story, associating each sound with parts of the story. As many associations as possible were established to fix the *sound of the letter*.

All who received this special training are reported to have improved greatly, in a short time. Schmitt concludes that there are a few children who are so constituted that they can-

not learn readily by the word and sentence method. "Every teacher uses this (the phonic method) to some extent, but to a very slight extent. The average child quickly learns to associate the printed letters and words with their vocal prototypes, without special emphasis on phonics, or special attention to associations.

"Whatever may be said for the word and sentence methods, it is really by the phonic method that the child becomes independent of the teacher."

In 1920 and 1921 Freeman and Gray respectively presented well-studied cases of individual pupils. Freeman's case was that of a girl 9 years and 6 months old, in the fourth grade of the University Elementary School, at Chicago. General intelligence was "better than average," the exact IQ not being stated. The child's father and paternal aunt had also had marked difficulty in reading. Both parents were above average in social-economic status, and hence probably also in intelligence. An oculist had made a diagnosis of word blindness, with a very discouraging prognosis for learning to read.

As a result of careful psychological analysis, it was decided that there was no deficiency of general intelligence, and no disorder of vision or of visual perception. There was no motor deficiency or general language disturbance. "The defect, therefore, must be a highly specialized one," apparently consisting in lack of aptitude for associating visual symbols with prescribed sounds.

Phonetic drill had already been carried to excess in efforts to teach this child. She centered all her attention upon "sounding" the words as units, with no grasp of thought units. Devices to extend recognition were instituted. Passages were broken up into sentences, the individual sentences being typed separately on slips of paper. A card was placed upon the page and moved forward as fast as the child could.

read. Flash-card work was undertaken. Printed directions were given, which the child followed out by appropriate action. Practice in reading arithmetical problems was prescribed, where it was necessary to read exactly every item. Parallel with instruction in reading there was instruction in spelling and writing. Deficiency in spelling was extreme.

From early in October to late in December, these drills were given. The improvement shown on tests of reading ability was very marked after this brief interval. There was no doubt that the child could learn to read, and the prospect of return to the grade normal for her age seemed very good.

Gray's case was that of a fourth grade boy, aged 10 years and 4 months when the study began. This boy had been obliged to discontinue some of his school work, because of inability to read fluently and effectively. His parents were unusually intelligent, and his sister read well and much.

The boy was normal physically, active and robust. At the age of 4 years, he began to wear glasses to correct astigmatism and myopia, and was constantly under the advice of an expert oculist.

There was a very irregular school history, with "skipping" in grades 1, 2, and 3. General intelligence was slightly better than average, as taken by the Stanford-Binet. Ability was rated good in all phases of school work not requiring reading. On all tests of reading ability he made very low scores. Comprehension was good for material read to him.

It was seen that he recognized words individually, that his eye-movements were faulty, and that the mechanics of reading had not been rendered automatic. Special practice exercises were prescribed in recognition of words, in control of eye-movement, and in grouping words in thought units. Very marked improvement followed upon this individual instruction, for one hour a day, over a period of two months.

A careful analysis, followed up by experimental teaching, has been published by Fernald and Keller. Seven non-readers of normal vision, and of IQ's ranging from 94 to 130, were studied. All learned to read, under special instruction. The method of teaching stressed tracing, writing, and pronouncing the words. That is, the kinæsthetic elements in reading were emphasized.

Fernald and Keller believe that these children had not learned reading, because ordinary methods of teaching neglect the "kinæsthetic links." Strong motor tendencies were seen in the children, even after they had learned to read fluently. It must be said that this study is one of the most satisfactory so far presented, because it gives precise quantitative measurements, and because the psychological analyses were so well checked up by experimental teaching.

Gates followed up the poorest readers, all of average or superior general intelligence, in the Scarborough School, with special training in the visual perception of words, with good results in every case but one.

Comment upon the implication of these studies will be postponed until we have considered certain further contributions to the subject, for example Burt's observations on neurotics.

VI. NERVOUS INSTABILITY AND SPECIAL DEFECT IN READING

Burt has pointed out what every psychologist who examines school children can confirm, that neurotic children are often deficient in reading, though they may be intelligent. This follows from the psychology of the mechanics of reading. Mastery of these mechanics calls for an ordinary degree of coöperation, adherence to definite directions, power of sustained effort, and fidelity to bare facts. Neurotics are those who are characteristically inferior in these essential quali-

ties, among others. Where impulsive response, negativistic attitude, flightiness, and illusion cause failure, neurotic children fail. Hence many of them never learn to read, except by individual teaching.

Under this category, we may consider, also, speech-defectives, for speech-defects are often symptomatic of nervous instability. Children who stammer or lisp may "turn against" reading, because of the ignominy they fear, in oral reading before their mates. A child who displays a speech-defect in oral reading should, for humane reasons, be excused from such reading before the class.

General nervous instability naturally tends to failure in any school subject, which demands the qualities of character mentioned above as essential to the mastery of reading. Thus nervous, but intelligent, children may be deficient in reading, spelling, and arithmetic, "the tool subjects," while making satisfactory progress in "the subject matter courses," such as history, nature study, or geography, where precise connections in prescribed sequences of relationships need not be formed, in order to succeed.

Nervous instability may be found in combination with any degree of IQ, apparently, from dullest to brightest. The relation between them is not certainly known, though there is now considerable indication that the correlation between stability and intellect will be found to be positive and high (but not perfect). This would mean that there are very probably more ill-balanced children among the stupid than elsewhere in the distribution of IQ. That organic quality, which shows itself in superior intelligence, robustness, and longevity, also shows itself in nervous stability, more likely than not.

A nervous child, who is also very stupid, will, of course, learn under individual instruction only what his limited in-

telligence will permit. The methods of mental measurement enable us to differentiate between the nervous child who can learn much, and the nervous child who can learn very little, under individual training.

VII. A FOUR YEAR STUDY OF A NON-READER

From February, 1918, to May, 1922, the present writer studied and taught a non-reader, a schoolboy.

X was brought to the Psychological Laboratory at Teachers College, in February, 1918, by his mother. The complaint was that the child could not learn to read, and on this account he had been suggested by his teachers for the ungraded class, in which feeble-minded children are taught. His mother, an intelligent woman, could scarcely believe X to be feeble-minded, because he "is very quick about things around home, is keen and capable about doing errands for money, and though he cannot read, gets around the city by himself." She felt, however, that a boy who after over six years of instruction still remained totally illiterate must require special advice of some kind.

Accordingly, when the suggestion in reference to the ungraded class was made, the mother took X to the Neurological Institute, where an examination was made, in the Psychological Laboratory. The report was then given that the child was not a proper pupil for such a class, and the matter was referred to Teachers College.

X was born on September 23, 1906. He was therefore 11 years and 5 months old when he was first seen by the present writer. His school history showed that he started to school in kindergarten at the age of 5 years, and went into the first grade at 6 years. He had been "left back" in nearly every class, after the study of reading began. He spent three terms

in 1A; one term in 1B; two terms in 2A; two terms in 2B; two terms in 3A; and was, when first examined, repeating 3B. In 3B he was reported as "deficient in everything except conduct." In conduct he was rated always as B+ or A. The teachers said they could not teach him.

When X was about 7 years old, the matter of his difficulties was first taken up, with the family physician, who said he would "grow out of it and be all right." As years passed, and the child continued to be untaught, the physician finally advised the visit to the Neurological Institute.

The teacher's opinion was that the boy must be feeble-minded, since five different teachers had tried to instruct him in reading and spelling, yet he had failed to read or spell any word, except his name. He could recognize his name among other words, and could *draw* it fairly well, much as he would draw a house or tree. He could not *spell* his name.

Vision and audition had been tested at the Manhattan Eye and Ear Infirmary, and the report was that no significant defect of eye or ear existed. Motor tests showed the boy to be right handed, so that interference in word-management, possibly due to change in "handedness," was eliminated.

The developmental history of X as an organism reveals nothing atypical, except defects of speech and difficulty in reading. He was born normally, walked and talked before he was two years old, and was normal in dentition. But he did not *talk plainly* till he was about 6 years old. He had a speech defect, stuttered, and could not say "I".

His medical history shows that he had whooping cough as a baby; that tonsils and adenoids were removed at the age of 5 years; that he had an abscess in the left ear at the age of 4 years, which lasted about two weeks, but did not impair hearing; that he had diphtheria at the age of 11 years, a bad case, followed by temporary paralysis of the soft palate;

that he had never had any convulsion or loss of consciousness ; that he had never had chorea, or other disease of the nervous system. Physically he was well developed, measurements on February 14, 1918, being as follows: Standing height, 59.8 inches; sitting height, 29.6 inches; weight (with ordinary clothing on), $86\frac{1}{4}$ pounds; cranial circumference, 21.2 inches; right grip (Smedley), 20 Kg.; left grip, 18 Kg.; lung capacity (wet spirometer), 130 cubic inches.

As for family history, X is the youngest of four siblings, all others of whom learned without difficulty to read and spell. His sister graduated from high school with a state scholarship, went through college, and is now a teacher in a high school. An older brother graduated from the elementary school at 14 years, in spite of the fact that he missed two semesters through illness. He also had a speech defect "about the same as X," but outgrew it. Another brother had reached 8B by the time he was 13 years old. Of thirteen cousins attending school, only one had ever been "left back."

The mother had graduated at the usual age from common school. The father had been troubled in boyhood by a speech-defect, which disappeared. "He could not say certain words and letters." On this account he did not like school. As an adult he reads the newspapers, and "can write a straight letter."

X had never known any language other than English, so that interference of habit from other languages was ruled out. No attempt had been made to teach him reading at home, until after the reports of his disability began to be made from the school.

General intelligence was measured by the Stanford-Binet Scale, with a resulting score of 9 years 9 months mental age, and IQ 85. It was thus seen that general intelligence was quite sufficient for learning to read. From general intelli-

gence of this degree, in a child under ordinary instruction for six years, one would usually be justified in predicting close to a fourth grade score on tests of reading.

In this case, however, scores of zero were yielded on all tests of ability to read. No word or letter on any scale could be read. There was, therefore, no question of making an analysis of the child's difficulty through the use of such tests, since all scores were uniformly zero.

X was anxious to learn, and was becoming self-conscious because of his failure to go ahead. At this time no speech defect was noted by the examiner, and it was supposed to have been "outgrown." He could copy writing, with some errors, and, as seemed strange, could transpose print into writing, though slowly and with errors.

Since sensory capacity was normal, general intelligence was developed well beyond the minimum at which reading can be taught, and character traits, such as promptness, reliability, and fidelity to duty, were reported to be better than average, it was decided to undertake to teach the child to read. Upon being asked whether he could travel alone from his school in Brooklyn to the office at Teachers College, both he and his mother replied without hesitation in the affirmative, "for he has ways of finding out where he is, without reading."

Accordingly, from February to June, 1918, X came three times a week to Teachers College, and received special instruction in reading and spelling from Miss Sara Fisk, at that time a graduate student in the Department of Educational Psychology. After some experimentation with the attempt to teach by the word and sentence as units, Miss Fisk decided to begin by teaching first the alphabet, and to proceed with the letter as the unit. X thus learned to read, by spelling out the letters, and "sounding" them as he went. In this

way, by the first of June, 1918, he knew and could sound and could write every letter of the alphabet, but could not write the capitals ; and he had a reading vocabulary of eighty simple monosyllables. He was advised to study through the summer vacation, if he could.

In October, 1918, X returned to the College, seeking instruction, but Miss Fisk had discontinued her studies, and no teacher was available at the moment. In March, 1919, X's mother reported that he had "done nothing" in reading and spelling at school, though he was not deficient in geography or arithmetic, and asked for assistance. Upon this report, X was invited to come for further instruction, which was given thereafter by the present writer.

The method previously undertaken was continued. The *Riverside Primer* was mastered, between March and June of 1919. Each new word was learned by spelling aloud and sounding. After several repetitions of this process, a new word would be assimilated into the vocabulary which could be read at sight, with the word as the unit of perception. In June of 1919, X could read any word in the *Riverside Primer*, either at sight or by spelling, and could write without error every letter of the alphabet, both small letters and capitals. He could also read simple matter which interested him in daily life, such as the weather reports, from newspapers.

From October, 1919, to June, 1920, X came for one hour each week, to be instructed. The *Riverside First Reader* was studied through. He made steady progress, as may best be seen from the repeated measurements on Trabue's "Language Scale A," which are illustrated in Figure 6 (page 77).

In September, 1920, X entered grade 5B, being 14 years of age, three years retarded in school status, by the New York City age-grade norms. His speech defect was again noticeable. All through this year, till June, 1921, he came for one

hour each week to take instruction in reading and spelling. The series of Riverside readers was now abandoned, in favor of the history and other books used regularly in grade 5B. Toward the end of that school year, some reading was also done from boys' stories, in which X had spontaneously become interested during the summer of 1920.

From October, 1921, to May, 1922, stories written for boys were used as material for the reading lesson. X brought with him whatever book he happened to be reading at the moment, and the lesson was taken from it. By this time X had become so fond of silent reading as a pastime that several difficulties in oral reading, not previously present, developed. One of these was the tendency to guess at new words, without waiting to perceive them accurately, in order to get on with the story. Another was the tendency to leave out all well known and unimportant monosyllables, such as "and," "the," "but," "of," "who," and so forth. These words he knew unerringly when he could be induced to look at them, but in silent reading he had evidently formed the habit of neglecting them altogether. These faults were corrected by practice in reading backwards, which offers no incentive to skip words.

Samples of X's tests in reading are reproduced in Figures 6, 7, and 8, in order that an accurate idea may be conveyed of his growth in power to gain meaning from the printed page.

X's account of a week's reading, reproduced in Figure 9 (page 86), gives an idea of the amount of outside reading regularly done, and at the same time an idea of proficiency in writing and spelling words, attained in January, 1922.

A partial list of books read for pleasure, on his own initiative by X, between December, 1921, and May, 1922, gives an idea of the practice he had in silent reading outside of formal instruction. This is presented on page 85, as follows.

Feb. 14, 1918.

ON EACH LINE WRITE THE WORD WHICH MAKES THE BEST MEANING
ONLY ONE WORD ON EACH BLANK

1. The sky _____ blue.
2. We are going _____ school.
3. The kind lady _____ the poor man a dollar.
4. The _____ plays _____ her dolls all day.
5. Time _____ often more valuable _____ money.
6. Boys and _____ soon become _____ and women.
7. The poor baby _____ as if it were _____ sick.
8. The _____ rises _____ the morning and _____ at night.
9. It is good to hear _____ voice _____ friend.
10. She _____ if she will.
11. The poor little _____ has _____ nothing to _____ ;he is hungry.
12. The boy who _____ hard _____ do well.
13. Men _____ more _____ to do heavy work than women.
14. It is a _____ task to be kind to every beggar _____ for money.
15. Worry. _____ never improved a situation but has _____ made conditions _____
16. A home is _____ merely a place _____ one _____ live comfortably.
17. It is very _____ to become _____ acquainted _____ persons who
_____ timid.
18. To _____ many things _____ ever finishing any of them _____ a
_____ habit.
19. One's real _____ appears _____ often in his _____ than in his speech.
20. When one feels drowsy and _____ it _____ happens that he is _____ to fix his
attention very successfully _____ anything.
21. The knowledge of _____ use fire is _____ of _____ important
things known by _____ but unknown _____ animals.
22. _____ that are _____ to one by an _____ friend should be pardoned
_____ readily than injuries done by one _____ is not angry.
23. To _____ friends is always _____ the _____ it takes.
24. One ought to _____ great care to _____ the right _____ of habits, for one
who _____ bad habits _____ it _____ to get away from them.

FIG. 6—Part 1.

The five parts of Figure 6 show how X improved as measured by Trabue's "Language Scale A," from Feb., 1918, to Dec., 1921.

Nov. 21, 1919.

ON EACH LINE WRITE THE WORD WHICH MAKES THE BEST MEANING
ONLY ONE WORD ON EACH BLANK

1. The sky _____ blue.
2. We are going to school.
3. The kind lady _____ the poor man a dollar.
4. The _____ plays _____ her dolls all day.
5. Time _____ often more valuable _____ money.
6. Boys and _____ soon become _____ and women.
7. The poor baby _____ as if it were _____ sick.
8. The _____ rises _____ the morning and _____ at night.
9. It is good to hear _____ voice _____ friend.
10. She _____ if she will.
11. The poor little _____ has _____ nothing to _____ ; he is hungry.
12. The boy who _____ hard _____ do well.
13. Men _____ more _____ to do heavy work than women.
14. It is a _____ task to be kind to every beggar _____ for money.
15. Worry _____ never improved a situation but has _____ made conditions _____
16. A home is _____ merely a place _____ one _____ live comfortably.
17. It is very _____ to become _____ acquainted _____ persons who
_____ timid.
18. To _____ many things _____ ever finishing any of them _____ a
_____ habit.
19. One's real _____ appears _____ often in his _____ than in his speech.
20. When one feels drowsy and _____ it _____ happens that he is _____ to fix his
attention very successfully _____ anything.
21. The knowledge of _____ use fire is _____ of _____ important
things known by _____ but unknown _____ animals.
22. _____ that are _____ to one by an _____ friend should be pardoned
_____ readily than injuries done by one _____ is not angry.
23. To _____ friends is always _____ the _____ it takes.
24. One ought to _____ great care to _____ the right _____ of habits, for one
who _____ bad habits _____ it _____ to get away from them.

FIG. 6 — Part 2.

Feb. 11, 1920.

ON EACH LINE WRITE THE WORD WHICH MAKES THE BEST MEANING
ONLY ONE WORD ON EACH BLANK

1. The sky is blue.
2. We are going to school.
3. The kind lady gave the poor man a dollar.
4. The boy plays with her dolls all day.
5. Time is often more valuable than money.
6. Boys and girls soon become men and women.
7. The poor baby cried as if it were sick.
8. The sun rises in the morning and sets at night.
9. It is good to hear one's voice from one's friend.
10. She will if she will.
11. The poor little child has nothing to eat; he is hungry.
12. The boy who tried hard did do well.
13. Men are more likely to do heavy work than women.
14. It is a hard task to be kind to every beggar without giving for money.
15. Worry never improved a situation but has made conditions worse.
16. A home is not merely a place where one can live comfortably.
17. It is very difficult to become well acquainted with persons who are timid.
18. To do many things without ever finishing any of them is a bad habit.
19. One's real character appears more often in his actions than in his speech.
20. When one feels drowsy and sleeps it often happens that he is unable to fix his attention very successfully on anything.
21. The knowledge of how to use fire is one of the important things known by man but unknown to animals.
22. Wrong that are done to one by an old friend should be pardoned more readily than injuries done by one who is not angry.
23. To please friends is always easier than the work it takes.
24. One ought to take great care to form the right kind of habits, for one who has bad habits must try to get away from them.

Apr. 7, 1920.

ON EACH LINE WRITE THE WORD WHICH MAKES THE BEST MEANING
ONLY ONE WORD ON EACH BLANK

1. The sky is blue.
2. We are going to school.
3. The kind lady gave the poor man a dollar.
4. The dolls plays all her dolls all day.
5. Time is often more valuable than money.
6. Boys and girls soon become women and women.
7. The poor baby acts as if it were sick ~~sick~~.
8. The riser rises at the morning and sleeps at night.
9. It is good to hear a voice sad his friend.
10. She will if she will.
11. The poor little bird has nothing to eat ; he is hungry.
12. The boy who works hard will do well.
13. Men are more likely to do heavy work than women.
14. It is a hard task to be kind to every beggar without for money.
15. Worry never improved a situation but has made conditions worse.
16. A home is not merely a place where one can live comfortably.
17. It is very difficult to become acquainted with persons who are timid.
18. To do many things without ever finishing any of them is a bad habit.
19. One's real self appears more often in his actions than in his speech.
20. When one feels drowsy and falls it often happens that he is unable to fix his attention very successfully on anything.
21. The knowledge of the use of fire is one of the important things known by man but unknown to animals.
22. Wrong that are done to one by an enemy friend should be pardoned more readily than injuries done by one who is not angry.
23. To be friends is always easy the hard it takes.
24. One ought to take great care to break the right kind of habits, for one who has bad habits should it try to get away from them.

Dec. 2, 1921.

ON EACH LINE WRITE THE WORD WHICH MAKES THE BEST MEANING
ONLY ONE WORD ON EACH BLANK

1. The sky is blue.
2. We are going to school.
3. The kind lady gave the poor man a dollar.
4. The girl plays with her dolls all day.
5. Time is often more valuable than money.
6. Boys and girls soon become men and women.
7. The poor baby is as if it were very sick.
8. The sun rises in the morning and at at night.
9. It is good to hear a voice of your friend.
10. She can if she will.
11. The poor little bird has if nothing to eat; he is hungry.
12. The boy who works hard will do well.
13. Men do more at to do heavy work than women.
14. It is a hard task to be kind to every beggar that asks for money.
15. Worry. _____ never improved a situation but has _____ made conditions _____
16. A home is a merely a place _____ one _____ live comfortably.
17. It is very _____ to become _____ acquainted _____ persons who
_____ timid.
18. To _____ many things _____ ever finishing any of them _____ a
_____ habit.
19. One's real _____ appears _____ often in his _____ than in his speech.
20. When one feels drowsy and _____ it _____ happens that he is _____ to fix his
attention very successfully _____ anything.
21. The knowledge of _____ use fire is _____ of _____ important
things known by _____ but unknown _____ animals.
22. _____ that are _____ to one by an _____ friend should be pardoned
_____ readily than injuries done by one _____ is not angry.
23. To _____ friends is always _____ the _____ it takes.
24. One ought to _____ great care to _____ the right _____ of habits, for one
who _____ bad habits _____ it _____ to get away from them.

April 15, 1921.

Read this and then write the answers. Read it again if you need to.

Both before and after Christmas, Bob Adams worked harder than he did in the spring, summer or fall. Only very rarely did he reach home before eleven o'clock; and on every morning except Sunday he was up at six, dressed and done with breakfast by quarter of seven, left the house at ten minutes of seven and reached Mr. Clark's store at ten minutes of eight. In spite of the long hours and hard work, he was happy because his pay had been raised twice.

14. What was the cause of Bob's pleasant feelings?...

that he should not play work

15. What other person besides Bob is mentioned in

the paragraph? *the store keeper*

16. How often did Bob reach home before eleven

o'clock? *almost every night*

Read this and then write the answers. Read it again if you need to.

Nell's mother went to the store on Water Street to buy ten pounds of sugar, a dozen eggs and a bag of salt. She paid a dollar in all. Nell and Joe went with her. On the way home on Pine Street, they saw a fire-engine with three horses.

17. Who paid for the sugar? *ten lb.*

18. Where did Joe go? *Joe went with his mother to the store*

19. Whose mother went shopping? *Nell and Joe mother*

Do the next page.

FIG. 7 — Part 1.

The two parts of Figure 7 show X's improvement in silent reading, from April 15, (On the latter date, X answered 23 questions correctly, scoring

Dec. 2, 1921.

Read this and then write the answers. Read it again if you need to.

Both before and after Christmas, Bob Adams worked harder than he did in the spring, summer or fall. Only very rarely did he reach home before eleven o'clock; and on every morning except Sunday he was up at six, dressed and done with breakfast by quarter of seven, left the house at ten minutes of seven and reached Mr. Clark's store at ten minutes of eight. In spite of the long hours and hard work, he was happy because his pay had been raised twice.

14. What was the cause of Bob's pleasant feelings?...

..... *he got a raise twice*

15. What other person besides Bob is mentioned in the paragraph?... *Clark*.....

16. How often did Bob reach home before eleven o'clock?... *not very often*.....

Read this and then write the answers. Read it again if you need to.

Nell's mother went to the store on Water Street to buy ten pounds of sugar, a dozen eggs and a bag of salt. She paid a dollar in all. Nell and Joe went with her. On the way home on Pine Street, they saw a fire-engine with three horses.

17. Who paid for the sugar?... *Nell's Mother*

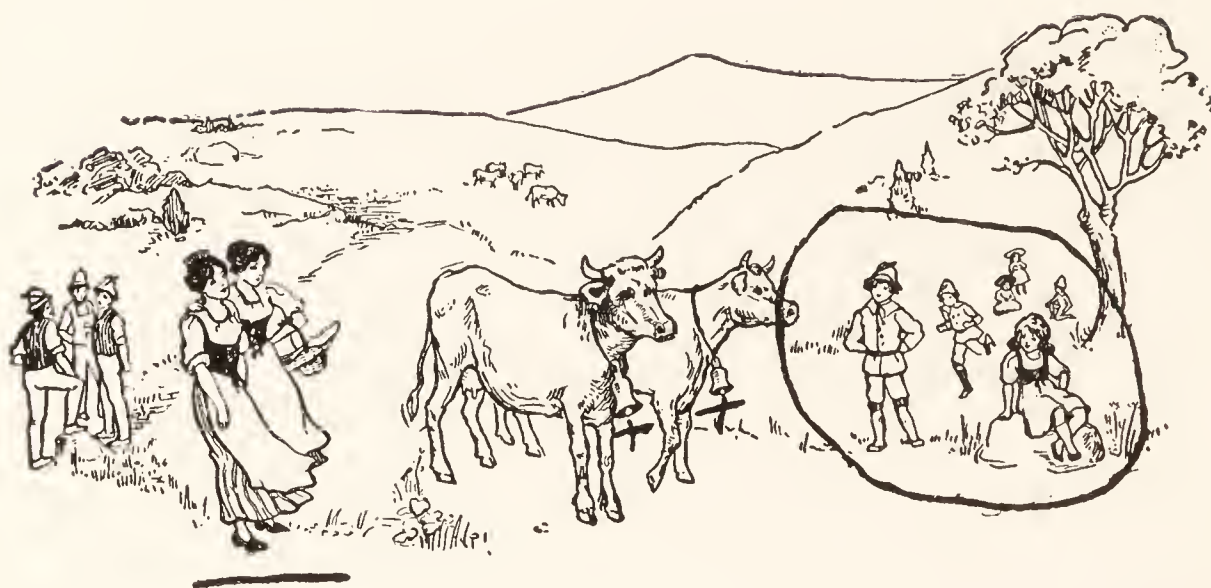
18. Where did Joe go?... *with Nell and her mother*

19. Whose mother went shopping?... *Nell's*.....

Do the next page.

FIG. 7 — Part 2.

1921, to Dec. 2, 1921, as measured by Thorndike-McCall "Reading Scale," Form 1. 52 points, which is the norm for the end of grade 6 B.)



In a country far across the sea is a land of mountains and valleys and many wonderful lakes and rivers. When the spring-time covers the mountain sides with fresh green grass, thousands of cattle are driven up into them to graze during the summer. Here they are watched and tended by the men from the villages, while the women are busily preparing butter and cheese for the market. The men hang bells about the necks of the cows so that they can locate those which wander from the herd. In the fall, when the cattle are driven down again into the valleys, there is great rejoicing and a holiday among the children.

19. Draw a line under those who spend the summer preparing food for the market.
20. Draw a ring around those who make merry in the fall.
21. Draw a cross under what helps the men locate the wandering cows.

FIG. 8. — Showing X's ability to get meaning from printed words, in May, 1922, as tested by Haggerty's "Sigma 1," for grades 1 to 3. This does not represent X's maximum ability, but is presented as a sample of his work on this scale.

Two Young Patriots. E. T. Tomlinson.
Ralph on the Overland Express. Allen Chapman.
Scouts of Stonewall. J. A. Altsheler.
Army Boys on the Firing Line. Homer Randall.
Among the Malays. G. A. Henty.
Ralph in the Rocky Mountains. Allen Chapman.
The Outdoor Chums at Cabin Point. Quincey Allen.
Huckleberry Finn. Mark Twain.
Andy at Yale. Roy E. Stokes.
Adventures of Sherlock Holmes. Conan Doyle.

Repeated mental tests of X resulted as follows :

Stanford-Binet	{	Feb. 14, 1918.	M. A. 9-9.	IQ 85. ¹
		Dec. 5, 1919.	M. A. 11-3.	IQ 85.
		Jan. 6, 1922.	M. A. 12-7.	IQ 82.

Pintner's "Scale of Performance Tests." Dec. 26, 1919.
 Median M. A. 11-0.

Healy's "Pictorial Completion No. I." 446 points. (11-year performance). Dec. 26, 1919.

Healy's "Pictorial Completion No. II." 55 points.
 Dec. 26, 1919.

Stenquist "Mechanical Tests," Series I. Feb. 3, 1922.
 Raw Score, 54 points. T score, 61.

It is of interest to note that a scale like Stanford-Binet, against which has been repeatedly brought the *a priori* objection that it depends on verbal acquirement, is capable of differentiating a non-reader from the feeble-minded. It is also interesting that the Pintner "Scale of Performance Tests," which does not include ability to read at all, gives almost exactly the same result as the Stanford-Binet, in this case.

X is a boy of superior character. He never missed an appointment with his instructor, and was never tardy except

¹ If alternates are counted instead of the four tests which directly involve reading or spelling, these IQ's become 88, 85, 87, respectively.

Jan: 27, 1922.

This week I read:

A Thousand Leaps under the sea.

The boy scoted at camp.

The Liberty boys on the Brandywine

FIG. 9. — Showing an account written by X of his week's reading.

once, unavoidably. He gave up pleasures, such as trying out for baseball, in order to learn reading. When asked why he did so, he replied that "You most probably can't get a living playing baseball, but you can get a better living if you can read." These qualities of perseverance and fidelity to duty were undoubtedly very important factors in such success as was achieved.

Why did X not learn to read as children of his general character and endowment usually do, in the ordinary course of schooling? After four years of studying and teaching him, the present writer cannot give a definite answer to this question. He was finally taught to read by a method in which the letter is the unit of perception, and in which words are read in the first place by spelling them aloud. This is not the method used in the schools where X attended, nor in any modern school.

Still, the possibility of teaching him by some method other than that which succeeded, has not been excluded. It is even possible that he might have learned to read by the very method used in the schools, under individual instruction, where each habit can be scrutinized as it is being formed. In a class of forty or fifty children, each demanding attention, a teacher cannot succeed with an individual pupil, by any method, as well as with that pupil alone, by that same method.

It was observed throughout the teaching of X that he constantly made appeal to his ear. He could always grasp a difficult word more easily by hearing it spelled aloud, than he could by seeing it. In order to obtain some quantitative statement of the extent to which auditory perception showed an advantage over visual perception in his case, the following experiment was tried.

In the spring of 1922, on four successive weekly appointments, 27 paragraphs, comprising 4131 words, were read by

X, both (1) *through the ear*, the teacher spelling the words, and X pronouncing them without seeing them, and (2) *through the eye*, X seeing and saying the words, in the usual way. The order of these procedures was reversed for alternating paragraphs, so that no advantage to either method of perception would accrue from practice.

Errors are of two kinds — misreadings and omissions. Omissions in sight reading were not counted, since, according to the method whereby the teacher spelled successive words to X, no omissions were possible. Misreadings only were counted. In reading these paragraphs, X made 162 errors through the eye, and but 57 errors through the ear, in perceiving the same words.

This great reduction in error through auditory channels might, however, be due to the fact that by that method only one word was presented at a time, whereas in the ordinary visual reading the whole page of words was presented, acting as a distraction. In order to check this possible error in interpretation, one hundred isolated words were presented to the eye and to the ear, reversing the procedure alternately for every ten words. The ratio of error was nearly the same as in the first experiment. X can now, in fact, pronounce almost any puzzling word in ordinary reading matter, such as is found in newspapers, by spelling it aloud.

It seems reasonable, therefore, to infer that there are certain specific attributes of the auditory elements in reading, which were especially important for education, in this boy's case, and which were not much utilized by the method of teaching employed. By teaching him the letter, with its various possible sounds, as the unit of perception, we supplied him with a tool which enables him to construct words for himself, through the channels which are easiest for him. This has not rendered him fluent, but it has rendered him literate.

Altogether, he had from us about a hundred and fifty hours of special instruction. The present writer believes that with several times as much practice as X has had, he will become a reasonably fluent sight reader, dropping out the spelling almost entirely.

This case is very much like those referred to by Hinshelwood, and it is interesting that the teachers adopted, after trial and error, the same method adopted by Hinshelwood, without being familiar at that time with Hinshelwood's contribution.

Inasmuch as a certain practical interest attaches to the final outcome of educational adjustment in such cases, it may be stated that X at the age of sixteen years will leave the elementary school, having completed grade 6B. He will then seek admission to a trade school, maintained by one of the great industries.

VIII. SUMMARY OF STUDIES OF NON-READERS

We see, therefore, that non-readers, of general intelligence much above the minimum level required for reading, do learn to read when special training is given. This training may stress phonics (Schmitt), it may stress the motor and kinæsthetic avenues of approach (Fernald and Keller), or it may stress visual perception (Gates). It may or may not proceed by use of the old "alphabet" method (Hinshelwood).

What is the interpretation of the facts reported? Does it not seem certain that *general intelligence* is, as indicated by the high coefficients of correlation obtained between reading and intelligence, the chief consideration, in predicting whether or not a child will learn to read? Would it not appear that children of adequate general intelligence, and of normal sensory capacity, learn to read when given intensive training, whatever avenue of approach may be particularly stressed?

It is not credible that all the non-readers found by Schmitt in Chicago, chanced to have a kind of disability approachable by phonics, and in no other way; that those discovered by Fernald and Keller in California were so constituted that they could be approached through motor exercises, and not otherwise; that Gates' cases in the Scarborough School all happened to be susceptible to training through visual methods, and through no others. In fact, no investigator has established his or her method as the only method of successful approach to particular cases, by excluding other methods through experimental teaching.

For non-readers such as have been described under the criteria laid down by the investigators quoted, it seems highly probable that the best method would be that wherein all the avenues of approach are fully utilized. Such a method would combine all the special exercises devised by the various investigators, in a proportion and sequence, which should be determined upon as optimum by experimental teaching.

Such a method, when experimentally established, would be most suitable for all children — not for the extreme of the distribution exclusively. Here, as in so many questions of pedagogy, all children might profit from our study of the extreme cases, who differ from the typical in degree only.

Children of normal sensory capacity, and of IQ average or superior, typically learn to read passably well, without approach through all the possible avenues, and without special attention on the part of the teacher to all the elements involved. A few such children require intensive teaching in order "to pass" in reading, because of specific idiosyncrasies. If the methods that succeed with the extreme cases were applied to the typical class, perhaps the children might learn to read, not "passably," but very well. There might be a rise of ten points in norms for reading ability throughout the

grades. Such perfection of method might or might not eliminate entirely the necessity for individual teaching of special cases. Probably it would not, in classes as large as those seen in most of our public schools to-day.

IX. CASES OF SPECIAL ABILITY IN READING

It is characteristic throughout of educational psychology, that much more is known concerning the unable than is known concerning the able. The welfare of the strong is neglected by science and by education. It follows that the bibliographies dealing with the deficient, the sick, and the erring are very long, while those dealing with the gifted, the extremely healthy, and the unusually upright are very brief. Modern society gives a very disproportionate amount of time, money, and sympathy to its least profitable members.

The few cases of extreme special forwardness in reading, which are available for reference, are of children who were probably of very high IQ. Most of them were avowedly so. Terman has supplied numerous instances of children who learned to read in the third or fourth year of life, all of them of more than 130 IQ. Francis Galton, who could read fluently when he was 4 years old, was probably of IQ near 200, as has been gleaned from other biographical evidence. Ability to read is in such cases not special.

In 1910, the case of Otto Pöhler was reported. He was a child in Braunschweig, who could read German and Latin at the age of 1 year and 9 months, and also could read German numerals. The subsequent history of this infant shows that at the age of 15 years, he was an *Obersekunder* in the *gymnasium*, and that at 17, he was within one and a half years of the University. It is certain, therefore, that general intelligence was superior, but the degree of superiority cannot be guessed, except within wide limits.

It seems probable that the ability to read was somewhat special, in the sense that it exceeded the expectations from IQ. In order to read fluently before the second birthday, a child's IQ would have to approach 300, to coincide with expectations. From what we know at present of the limits of IQ, it would be impossible for any child to stand at 300 IQ. The case of Otto Pöhler is, therefore, probably one of especially great ability to read, in a child of generally superior endowment.

A similar case is that of Martha, communicated anonymously by her father, through Terman. Martha was seen by Terman at the age of 2 years, when she read fluently from an ordinary primer. The method and amount of instruction which led to this astonishing result, are set forth in the account. Expectation from reading ability alone would place Martha's IQ at something near 300, for she read what a typical child of 6 years can read. Later Terman tested the general intelligence of this child, and obtained a rating of 150 IQ.

Thus Martha's phenomenal ability to read must be considered special, in the sense that IQ fell far short of expectation therefrom.

A year ago a child was brought to the present writer for mental examination, because he could read newspapers fluently at the age of 4 years. Upon being measured for speed and accuracy in oral reading, he fell at the 10-year norms (fifth grade). An IQ of over 200 would be inferred from this, assuming the ability in mechanics of reading to be in no way special. As a matter of fact, IQ fell at 142. Scores for comprehension of reading fell at 7 years (second grade norms), corresponding with general intelligence.

Upon retests this year, the scores were as follows: mechanics of reading English (speed and accuracy), fifth grade norm; comprehension in reading, high third grade norm; mental age, 8 years 6 months; IQ 147. This child's ability to read is

special, though general ability in mental work is very superior, too.

These are all cases of generally gifted children, where mastery in the mechanics of reading is, however, in each case much beyond performance in other respects. Cases where test scores have been presented to show special discrepancies in reading, in children of very inferior IQ, have been reported by White, in collaboration with Poull, from the psychological laboratory of the institution for feeble-minded children, in New York City. The children in the school who could read were canvassed, and those who could not read were similarly canvassed, until two groups of five each were selected, all members being above six years mental age, where reading can typically be learned. The two groups compared as follows in age, general ability, and schooling.

	M. A.	IQ	Age	Years at School
Reading Group	6—8	69	9—8	2.2
Non-reading	“ 7—10	68	11—8	4.8

It is thus seen that the non-readers have every advantage, being one year higher in mental level, having had a double amount of schooling, and being of the same IQ¹ as the readers. The investigators then had before them two groups of generally inferior children, of which the members of one had ability to learn reading, not possessed by members of the other.

Tests based on investigations of the psychology of reading were then given. These were for auditory and visual acuity, ability to perceive and reproduce articulate sounds, ability to cross out A's and to check numbers, to attend to several impressions instantly, and to associate numbers and other symbols through the eye and through the ear. No significant

¹ For all practical purposes, IQ's differing from each other by not more than 5 points are equal.

differences in group scores were found, except in the last tests mentioned — those of forming associations between symbols. Here the readers made reliably higher scores than did the non-readers.

The investigators did not measure the reading ability of their subjects, but selected the children from the school reports, as to “reading” and “not reading.” The precise extent of specialized discrepancy between general intelligence and reading ability among the children cannot, therefore, be calculated. However, it may be inferred that two of these children had some degree of special ability. One of these, IQ 67, mental age, 6 years 7 months, is described as the best reader in the group, and it is said of her that she “reads well.” Another, IQ 79, mental age, 6 years 7 months, is said to “read very well,” being then in the second year of attendance on school.

A few cases of superior ability to read, occurring in combination with low IQ, have also been reported by Bronner.

X. THE SIGNIFICANCE OF LITERACY

Reflection will show at once the great importance of reading for school progress, since our schools are virtually reading schools. Almost no subjects included in the curriculum can be learned without mastery of reading. Also the importance of literacy for life in modern times can scarcely be overstated. Those who learn to read easily at an early age thus have a natural advantage; while those of good intelligence, who have difficulty, should be assisted in every way to learn.

There are certainly very few children of IQ over 100, with normal eyes and ears, who do not learn with ease to read. A census would doubtless show that most cases of special disability in this respect lie between 50 and 100 IQ, that is, in the

lower half of the distribution for general intelligence. Fildes, who measured the general intelligence of twenty-six non-readers, whom she studied, found them distributed as follows, with respect to IQ (Stanford-Binet) :

IQ 111	1 child
IQ 82-88	4 children
IQ 70-79	8 children
IQ 50-69	13 children

It may be argued that children who cannot read necessarily tend to fall low on Stanford-Binet, because the tests composing the scale are weighted against non-readers. The validity of this argument is doubtful, in view of the fact that but four out of seventy-four tests (not including alternates, of which none require reading) directly involve ability to read or spell. As a matter of fact, Fildes found no correlation among her twenty-six subjects, between IQ and ability to read, as measured by reading tests. "Two of the worst readers were the least intelligent and most intelligent boys. The three worst cases examined, *i.e.*, cases with no reading power at all, had intelligence quotients of 61, 79, and 78 respectively. Many defective boys with such high intelligence quotients read quite well."¹

Non-readers who fall between 80 and 100 IQ are especially worthy of attention, since they have sufficient general intelligence to make considerable use of reading, and to suffer a special handicap from illiteracy.

It may be confidently stated, as a result of the research of the past five years, that all children of average or better than average general intelligence are capable of literacy ; and that very early use of and interest in reading are strongly symptomatic of general superiority in selective thinking. From these

¹ Fildes' subjects ranged in birthday age from 9 to 16 years. In criticism it should be stated that correlation between IQ and ability to read cannot be clearly interpreted unless an array of birthday ages is given in conjunction. Fildes does not give such an array.

facts we may hark back to the conclusion of the physiological psychologists, Ladd and Woodworth: "Indeed, the entire cerebrum would seem to be, of necessity, involved in man's linguistic attainments and uses." Mastery of language is, as Binet concluded, one of the most reliable indications of competence in general.

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CHAPTER V

SPELLING

I. COHERENCE AMONG LINGUISTIC FUNCTIONS

ACCORDING to Meumann, the whole field of language is a unit, psychologically considered. Reading, spelling, composition, the learning of foreign languages should thus be intimately interconnected for a given individual. He who learns one readily, should also readily learn the others, without notable exception.

This view of the close coherence among linguistic functions is borne out, also, by the work of Gates, already cited, in which he found high positive correlations among perceptual tests which use words as materials.

We must notice, nevertheless, that the correlations fall considerably short of unity. Illustrative cases show that occasionally children are found who can read well, but cannot spell legibly, though the present writer has not seen cases of the opposite condition, and has not found them reported in the literature.

Special defect in spelling will, therefore, be given separate consideration, though it must be recognized that abilities in spelling and reading are usually closely associated.

II. ANALYSIS OF LEARNING TO SPELL

It is virtually impossible for an educated adult, whose spelling habits have long ago become automatic, to reconstruct from introspection the long, difficult, and complex processes

through which he passed in learning to communicate by means of correctly spelled words. Such an adult may gain some idea of what is involved in the spelling process by confronting himself with the task of learning to spell and write words upside down and backwards, but even so the experience of the child is not duplicated.

Analysis teaches us that this aspect of linguistic attainment ordinarily involves the formation of a series of connections approximately as follows :

(1) An object, act, quality, or relation is “bound” to a certain sound, which has often been repeated while the object is pointed at, the act performed, and so forth. In order that the connection may become definitely established, it is necessary (a) that the individual should be able to identify for himself the object, act, quality, or relation, and (b) that he should be able to recollect the particular vocal sounds which have been associated therewith. When this is accomplished, the sound has become a word.

(2) The sound (word) becomes “bound” with performance of the very complex muscular act necessary for articulating it.

(3) When school age is reached, certain printed and written symbols, arbitrarily chosen, visually representing sounds, become “bound” (a) with the recognized objects, acts, and so forth, and (b) with their vocal representatives, so that when the symbols are presented to sight, the word can be uttered by the perceiving individual. This is what we should call ability “to read” the word.

(4) The separate elements of the symbols (letters) become associated with each other in the proper sequence, and have the effect of calling each other up to consciousness in the prescribed order. When this has taken place we say that the individual can *spell orally*.

(5) The child by a slow, voluntary process "binds" the visual perception of the separate letters with the muscular movements of arm, hand, and fingers necessary to *copy* the word.

(6) The child "binds" the representatives in consciousness of the visual symbols with the motor responses necessary to produce the written word spontaneously, at pleasure.

This analysis is probably not exhaustive, but it provides a foundation on which to construct an understanding of poor spellers. Obviously, poor spelling may be due to one or another of quite different defects, or to a combination of several defects. In an ability so complex there is opportunity for the occurrence of a great variety of deficiencies. In any particular case the underlying cause can be discovered only by means of a psychological examination covering the various processes involved.

III. PSYCHOLOGICAL EXAMINATION OF POOR SPELLERS¹

Poor spelling, like poor reading, may be due to *sensory defects*, either of the ear or of the eye. If sounds are indistinct, or if visual stimuli are vague or distorted, the prescribed connections involving these elements will be difficult to form. Thus tests of auditory and visual acuity must be given. If any sensory defect is revealed, it should be corrected, if it is corrigible.

The degree of *general intelligence* must be determined. Failure to learn to spell is frequently symptomatic of general incompetence, though not so frequently as in the case of reading. The correlation coefficients cluster around .50 only, in the case of spelling and general intelligence. Quite a number of children will be found, whose achievement in spelling shows

¹ The substance of discussion under this topic is reprinted by courtesy of the *Teachers College Record*, from the issue of that journal for March, 1919.

marked discrepancy with general capacity. Spelling is more mechanical than reading, so that the stupid may more easily master it by tireless drill, while the intelligent are not likely to derive so much pleasure from it or to practice it so much.

The connections which are described in our analysis under (2) may be inadequately or incorrectly developed. This would be *faulty pronunciation*. This is undoubtedly a very prolific cause of poor spelling. Such errors as "a-f-t-e-r-w-o-o-d-s" for "afterwards," "w-h-e-n-t" for "went," "p-r-e-h-a-p-s" for "perhaps," will serve to illustrate this point. In observations on poor spellers, such errors are found by the score, and it is discovered that the words are pronounced as spelled. Thus the poor speller should be tested for the *pronunciation* of the words which he misspells. It may be that drill in correct pronunciation is what is needed, in order to improve his spelling.

Faulty pronunciation may itself be due to various causes. In the majority of cases it doubtless arises from *false auditory perception*, as in such misspellings as "hares breath" for "hair's breadth," and "Mail Brothers" for "Mayo Brothers." In other cases it arises from *inability to articulate properly*, as with children who stammer or lisp, or have nasal obstructions.

It may be that a pupil's weakness lies in the formation of connections, which we have noted in our analysis under (3). The formation of these connections involves *visual perception*, habits of interpretation through the eye, which have been found to be of first rate importance in spelling. We may refer back to the discussion of the perceptual factors in reading. In spelling, also, it has been discovered that error is not distributed at random, but follows certain laws. For instance, there is a constant tendency to shorten, rather than to lengthen words in misspelling them. The influence of any letter over error varies greatly with the position of the letter

in the word. The last halves of misspelled words show many more errors than are found in first halves. From these and other facts it is apparent that failures in visual perception contribute to the difficulties of poor spellers. In order to determine whether such is the case with any particular child, it will be necessary to make an analysis of his work, to see whether the distribution of his errors reveals such perceptual weakness. If a child can spell the first halves of words correctly, but does not spell the last halves, or if he learns to spell the upper halves of words correctly, but cannot spell the lower halves of them, the remedy is to bring about readjustments of attention, whereby he will *look at* those portions of words, which formerly he failed, unconsciously, to see.

Poor spelling may be due to sheer *failure to remember* — *failure to retain* impressions which were originally clearly and correctly perceived. This may mean simply that the child requires unusually numerous repetitions before he can form the connections described under (4) in our analysis; or it may be that his memory span is abnormally brief, and that he cannot easily associate more than three or four elements together as a unitary sequence. Tests of memory span for various kinds of materials should be instituted, in order to gain light on this point. If it appears that his performance is decidedly below the normal for his age, especially when the material is letters, it may be concluded that too brief memory span is probably playing a part in his difficulties. This could be checked up further by an analysis of his spellings, to see to what extent he spells short words correctly, but misspells longer words. Emphasis upon syllabication, prefixes, suffixes, and other short units should be helpful. The child might be able to remember three syllables of three letters each, but unable to retain, with the same amount of practice, one word of nine letters. Psychologically, these two tasks are different.

Smedley suggested years ago that there might be a "rational element" in spelling, whereby *knowledge of the meaning* of words would contribute to the correct spelling of them, in and of itself. Connections involving meaning are considered in our analysis under (1). Children produce an especially great proportion of error in spelling words which have no meaning for them. Hence it is of interest to test the child for knowledge of the meaning of words which he misspells. It is necessary to find out whether the words which confuse him are in his vocabulary.

Motor awkwardness and incoördination may contribute to poor spelling. Here are involved the connections discussed by us under (5) and (6). In written spelling (with which education is chiefly concerned), it is necessary not only to know what symbols are required, but to execute them successfully with arm, hand, and fingers. Here we must have recourse to motor tests, for steadiness, coördination, and speed of voluntary movement. Occasionally one finds a child who does much better at oral spelling than he does at written spelling. In such cases, improvement in handwriting is what is needed, either in respect to rate or quality. A slow writer may misspell many words if he attempts to hurry.

Many of the mistakes of poor spellers are merely *lapses*. These are errors committed by children who "know better," who can correct the mistake spontaneously as soon as attention is called to it. There are wide individual differences in the liability to lapse. It is difficult to see what remedial measures may be taken to improve those whose disability is due largely to lapsing, since lapses are not only involuntary, but for the most part unconscious; there is no awareness of them until one perceives them anew. Examples of lapsing may be seen in "Complicated *musich* which he heard played," and "It *mak make* an impression," for "It may make an impression."

One might suggest that children who show this tendency in marked degree should be trained to lay aside for a few minutes all written communications; then to take up their work and look anew at each word, in order to correct all lapses. It is not known experimentally how long an interval must elapse in order that writing may "get cold," so that lapses may be detected by the author of them. A few minutes will probably suffice.

Transfer of habits previously acquired is occasionally the cause of misspelling. Children who have learned to read and spell a phonetic language, like German, or a language that proceeds from right to left in spelling, are prone to difficulty with English spelling. The possible existence of such an influence is to be determined by taking the school history.

Sometimes it happens that the errors of the child are of one particular kind. Such *idiosyncrasies* may be exemplified by the case of a child who had a strong tendency to add final "e" to all words; and by the case of another, who was addicted to intrusive consonants, especially "m" and "n." These idiosyncrasies may doubtless be traced to their source in every case by a patient analysis of the child's mental contents. The child who added final "e" may, for instance, have been told by a careless teacher "Don't leave off your 'e's'." The cause of error will be different in every case. It is impossible to generalize about idiosyncrasies.

After all of the foregoing factors have been considered, there still remains the possibility that the failure to learn is due wholly or partially to *temperamental traits* — instability, indifference, lack of incentive, distaste for intellectual drudgery. English spelling calls largely for rote learning. It can be acquired only by the formation of thousands of specific bonds, arbitrarily prescribed. Its pursuit is almost inevitably tedious. Thus many children will be temperamentally ill adapted to become good spellers.

Failure in spelling, in an intelligent child, may thus result from various kinds of interference with prescribed habit formation. It is apparent that the psychological examination of a poor speller is neither a brief nor a simple task.

The direct examination of the individual should be supplemented by a family history, a development history, and a school history. In some cases special deficiency in spelling seems to be hereditary. Earle has made a study of the inheritance of capacity for spelling, from which he concludes that there is distinct fraternal resemblance in spelling. Stephenson has reported six cases of special inability to read and spell, which occurred in three generations of one family.

IV. CAN SPECIAL DEFECT IN SPELLING BE OVERCOME?

Spelling has received relatively little study as a process, in comparison with the attention which has been given to reading and arithmetic. We have no variety of experiments carried out to improve poor spellers, as we have in the case of poor readers. In 1918 the present writer reported, with Miss Winford, the results of studying and teaching a group of poor spellers, from the fifth grade. The experiment extended over two periods of ten weeks each, but the time was largely devoted to observations of the errors made, measurements of intelligence, and inventions of incentives for arousing interest in spelling as a group project. No child was taken individually, and given intensive instruction, as with the boy, X, in reading, reported in Chapter IV.

During the period of class teaching, all the poor spellers improved, as measured by the Ayres scale, but the three very poorest still remained at the bottom of the class. By intensive individual instruction any one of these three might have made much greater improvement.

We are, therefore, now in need of experiments carried out to improve poor spellers. Such experiments must include precise measurements of intelligence, ability to spell, ability to read, and amount of time expended. They must include a description of the sensory equipment of the spellers, and information on all points listed under the suggested outline for the examination of poor spellers. There must be an adequate account of method used, and objective measurements of improvement must be presented.

From knowledge of spelling as a process of habit formation, it would be predicted that any child of average intelligence, and normal sensory capacity, can learn to spell, if sufficient drill be undergone. English spelling is, however, relatively resistant to learning, because of the specific character of the connections to be made. Very few generalizations are possible, each word being to so great an extent a special matter. For this reason it is very important to teach first the words most commonly used. These have been ascertained by research in the Russell Sage Foundation.

V. DOES READING TEACH SPELLING?

In the *Atlantic Monthly* of October, 1921, an enemy of simplified spelling writes as follows: "Spelling is not a craft by itself: it is a part of writing and reading, training of eye and hand. When a boy writes 'starboard martyr' for 'Stabat Mater,' or 'forehead' for 'forward,' he writes what he hears; the fault is not with his ear but with his visual image of the words. It means that he is not a reader, and is not accustomed to the appearance of the words. To try to teach him the distinctions by lists of letters alone would be about as useless as to try to teach him to distinguish people he never saw by means of verbal descriptions."¹

¹ Quoted by permission of the Atlantic Monthly Press.

The Landing of the Pilgrims

Their where sum pepil that lived in England about 300 yers ago and the king at that tim that wanted all the pepil at that tim to go to his Chirch Their wher a set of pepil that where cald ceprates and thay where ponished siverly sum of them where thron into prisn and sum where hanged and sum where find and then thay went to Halond but thay dident stay very lond becose all their children ^{where} growing up in dutch fasions so thay went back to ~~halond~~ England and thay had to borow money for two ships and the nams of the ships where the spedwell and the may flour but the spedwell sprang a leak and had to turn back and it was a hard voyage and thay Landed 1620

FIG. 10. — Composition written at school by X in December, 1920. X was then in grade 5 B. The facts are correctly understood, but the spelling does not show great profit from previous reading of the text in history.

Have psychologists produced any evidence to show whether the view is correct, that reading will teach spelling? The positive correlation between ability to read and ability to spell does not, of course, give light on this question. Neither does correlation between amount of reading done and ability

Nov. 27, 1921.

Dear _____

I received your letter
and was very glad to hear from you.

I will be very glad to come
on Friday Dec. 2.

In the letter which you sent
me you wanted to know if I wrote
it.

I wrote it with a little help.
I am writing this one all
by myself.

yours respectfully

FIG. 11. — Letter written by X showing how he could spell by use of dictionary.

to spell, for the positive correlation, which would undoubtedly appear, might mean only that general intelligence determines both the amount of reading and accuracy of spelling, to the extent of positive correlation found.

The case of X, described in Chapter IV, is somewhat instructive in this connection. The necessity to learn reading was so urgent that it was soon decided to give no time to

spelling as such. The special teaching did not, therefore, include formal instruction in written spelling. The regular spelling lessons at school were, of course, taken by X, as well as might be.

After X had learned the letters thoroughly, so that he never erred in writing one, he made great improvement in his grades on the regular spelling lessons given at school, in which assigned words were learned by rote.

Words not thus specifically learned were spelled "by ear," with the general result which is exemplified in Figure 10.

X was taught the use of the dictionary, and by its aid he could spell as shown in Figure 11.

In German or Italian, the mutual helpfulness of reading and spelling would probably be much greater, for words in these languages are not nearly so specific in character as English words are.

VI. ILLUSTRATIVE CASES

Two cases are herewith given, to illustrate the marked discrepancies which may rarely be found between general intelligence and ability to spell. The first is that of a schoolboy of average intelligence, whose spelling is illegible. The second is that of a feeble-minded schoolgirl, whose spelling is very much above what would be predicted from mental age and IQ.

This boy was 14 years 2 months of age, and had been in school since the age of 6 years. His IQ was 93 (Stanford-Binet). He was referred for mental examination, because of failure to learn to read and spell. Figure 12 shows his attempts to spell the following words: *cannot, September, burned, houses, center, thousand, fifty, families, defends, bravely*.

The girl, who shows the opposite discrepancy, was in a school for the feeble-minded, at the time of examination. Her age was 12 years 6 months, her mental age 7 years 4

months, with an IQ of 59 (Stanford-Binet). She had attended school for 6 years. Figure 13 shows her ability to

can mat
supteber
bande
powur
genten
themche
sefety
bamater
tefonter
beaveley

FIG. 12. — Showing efforts to spell, of a 14-year-old schoolboy, of IQ 93, after eight years of school instruction. Illustrating extreme dissociation of spelling ability from general intelligence. Compare with Fig. 13.

spell the same words attempted by the boy referred to above.

On Ayres' scale, this feeble-minded girl scored at fifth grade ability, at least three years beyond expectation from general intelligence. The boy, of average intelligence, scored on the Ayres scale below first grade ability — at least seven years below expectation from general intelligence.

The girl could not learn subject matter, or manage her affairs any better than a 7-year-old child. The boy could work for money, was reliable and efficient in ordinary affairs, could master subject matter read to him, was expert in bird lore, and showed the general competence of a typical 14-year-old, except in reading and spelling.

One judging these individuals for practical purposes, on the basis of a test in spelling, would be profoundly deceived.

Figure 14 also exemplifies the spelling of a child whose general intelligence cannot be correctly inferred from performance in spelling. This child was 9 years 10 months old at the time this letter was written, her mental age being 14 years 1 month. The child had been three years in school. She learned reading very easily, reading at this time with fluency and grace of inflection. Her case, therefore, illustrates discrepancy between reading and spelling, as well as between spelling and general intelligence.

The inadequacies noted here were probably due to distaste for the drill which is required for mastery of spelling and punctuation. For bright children, reading is motivated by the fact that from it they gain ideas. In presenting ideas, it is not necessary to spell exactly, but only approximately. Hence very young, bright children may read accurately, but spell poorly.

cannot
September
burned
houses
center
thousandred
fifty
families
defends
bravely

FIG. 13. — Showing spelling of a 12-year-old girl, of IQ 59, after six years of instruction. Illustrating extreme dissociation of spelling ability from general intelligence. Compare with Fig. 12.

Dear mother
 we got your
 letter. I am vearry bissy
 ey just now for I am
 feckring my house
 up. your garden is
 yearry now I am sor-
 y to say. the one
 that is near my
 howse is the best it
 hade zeaney and a
 bud.

with loths
 of low

P.S. Juneey has had
 a good laught
 over the spelling
 is it rouny

FIG. 14. — Showing spelling of a child 9 years 10 months old, with IQ 143, after three years of instruction. Illustrating dissociation of spelling ability from general intelligence.

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CHAPTER VI

ARITHMETIC

I. RELATION BETWEEN IQ AND CAPACITY FOR ARITHMETIC

ARITHMETIC as a psychological process has been studied analytically by psychologists more assiduously than any other of the school subjects, except reading. The psychology of arithmetic began to be investigated more than thirty years ago by laboratory workers, but so complex are the functions involved that there still remains much to be known.

Correlations show that capacity for arithmetic is closely connected with general intelligence. Most of the children who fail in the subject do so as a symptom of a general lack of competence in thinking. The great majority of those who are notably excellent arithmeticians are also superior in other performances.

The four children of more than 180 IQ, mentioned in Chapter IV as having learned to read before or during the third year of life, are also fine mathematicians, excelling at lightning calculation and at thinking in terms of numerical relations. Here, again, their marvelous skill at numbers is but symptomatic of their rare general superiority. Although the correlation between general competence and capacity for arithmetic is high and positive, it is reduced from perfection by the occurrence of discrepancies. Occasionally a very intelligent child is found, who does not readily learn arithmetic, and on the other hand there exist children whose ability at calculation far exceeds expectation from other performances.

II. DISTINCTION BETWEEN ARITHMETIC AND MATHEMATICS

Psychologically as well as logically, there is a distinction between arithmetic and mathematics. In both respects the former is but one phase or branch of the latter. By arithmetic is meant those functions of mathematicians which involve numerical calculation. This includes the four fundamental processes, with whole numbers and fractions, enumeration, and the solution of problems requiring choice of process to be employed.

Mathematics includes arithmetic, and also the relationships of space, time, proportion, and probability, as subsumed in algebra, geometry, trigonometry, and calculus. Psychologists find a positive intercorrelation among abilities in these various branches of mathematics, which is, however, not sufficiently close to unity so that the possibility of marked specialization in some cases is excluded. Judd has concluded that the abilities demanded by algebra, geometry, and arithmetic represent, respectively, elements not included in the others. Lightning calculators have been recorded, who could accomplish nothing, apparently, in the derivation of formulæ, or abstraction of principles.

Rogers decided as a result of experimental tests of mathematical ability, that "a marked degree of the power to analyze a complex and abstract situation, and to seize upon its implications, is the most indispensable element in mathematical proficiency." This is the power that makes for proficiency in all life's difficulties, and he who has it has unusual general intelligence — not mathematical proficiency only. There is certainly slight possibility that a generally stupid individual can ever deal with "higher mathematics."

Since the processes other than the arithmetical have been

very little studied, the discussion of special aptitude in mathematics will here be restricted largely to aptitude for arithmetic.

III. MENTAL FUNCTIONS IN ARITHMETICAL CALCULATION

In his recent presentation of the psychology of arithmetic, Thorndike writes as follows :

“Achievement in arithmetic depends upon a number of different abilities. For example, accuracy in copying numbers depends upon eyesight, ability to perceive visual details, and short-term memory for these. Long column addition depends chiefly upon great strength of the addition combinations, especially in higher decades, ‘carrying,’ and keeping one’s place in the column. The solution of problems framed in words requires understanding of language, the analysis of the situation described into its elements, the selection of the right elements for use at each step, and their use in the right relations.”

A great number of habits, more or less specific, must be automatized. There are all the combinations used in addition and subtraction, the multiplication tables, the reading of large numbers, the manipulation of fractions, the placing of the decimal point, and many others. These habits are of very unequal difficulty. Ranschburg has shown, for instance, that $5 + 2$ is a much easier operation than is $2 + 5$, and that $5 + 5$ is easier than either. The difficulty of a combination is augmented by increase in the second member. The difficulty increases, also, as either or both of the members increase in value. The addition of two identical numbers, of whatever value, seems always to follow a different course from that of two unlike numbers, resembling multiplication in the time taken.

These are a few illustrations of the subtleties of habit formation in arithmetic, which are revealed only by laboratory methods. They suggest, also, the complexity and multiplicity of connections, which enter into ordinary achievement in arithmetic. Since the functions are thus highly complex and specialized, what are their interrelations? How are they organized, as regards the amounts of each found in given individuals?

IV. THE ORGANIZATION OF ARITHMETICAL ABILITIES

Thorndike and his students have shown that in general the correlation between ability in any one important feature of computation and ability in any other important feature of computation is positive and high. Thorndike holds that if enough tests were made to measure each individual fully in subtraction, multiplication with integers and decimals, division with integers and decimals, multiplication and division with common fractions, and computing with per cents, there would probably appear intercorrelations for a thousand 14-year-olds of near .90. Correlation between problem-solving and computation would doubtless be much less, probably not over .60.

Thorndike expresses the following inferences, based on interpretation of existing data.

“It should be noted that even when the correlation is as high as .90, there will be some individuals very high in one ability and very low in the other. Such disparities are to some extent, as Curtis and Cobb have argued, due to inborn characteristics of the individual in question, which predispose him to very special sorts of strength and weakness. They are often due, however, to defects in his learning, whereby he has acquired more ability than he needs in one line of work, or

has failed to acquire some needed ability, which was well within his capacity.

“In general, all correlations between an individual’s divergence from the common type or average of his age for one arithmetical function, and his divergence from the average for any other arithmetical function, are positive. The correlation due to original capacity more than counterbalances the effects that robbing Peter to pay Paul may have.”

In 1910, Brown undertook to determine whether there is a special capacity for mathematics, and concluded from his correlations that there is an especially close relationship among tests involving mathematical performance. Ten years later, Collar made an effort to secure further data as to whether arithmetical ability, as a unitary combination of capacities, exists. Two hundred schoolboys were tested in the investigation. Results led to the conclusion that arithmetical ability tends to be represented in two main divisions: (1) the power to compute with ease and readiness, and (2) the power to solve problems by arithmetic, which involves the application of a higher degree of ability than is required in computation.

Arithmetical tests of various kinds correlate more closely than do arithmetical tests with non-arithmetical tests. “Hence we are compelled to interpret this relationship as evidence distinctly in favor of Burt’s suggestion, that there is an essential unity in arithmetical ability.”

All investigators have agreed in finding the correspondence between computation and problem-solving much less than that found among the various processes of computation alone. The facts are here analogous to certain facts noted in the study of reading, in Chapter IV. There it was seen that between proficiency in the mechanics of reading and comprehension in reading there may occur marked disparity; and that it is

in mechanics that special discrepancies may be found between reading ability and general intelligence.

In arithmetic the same observation may be made. Marked special defects and talents are found in the mechanics of arithmetic, that is, in computation. But problem-solving in arithmetic is closely correlated with general intelligence, for it involves the capacities required for problem-solving anywhere, — response to many subtle elements, the weighing of these one against another, and choice of the procedure that will yield solution. These are the same capacities that underlie comprehension in reading, or grasp of any other situation offered by life. They are all functions measured in tests of general intelligence.

In school, arithmetical problems are usually presented as reading matter, so that reading for the comprehension of sentences is in itself of first rate importance for achievement in problem-solving.

V. PSYCHOLOGICAL STUDIES OF SPECIAL DEFICIENCY IN ARITHMETIC

Studies of children especially backward in arithmetic, with the accounts of the results of experimental teaching, have been contributed by Uhl, Smith, Schmitt, and others. Bronner has also contributed accounts of the psychological examination of such children.

Schmitt studied thirty-four pupils in the schools of Chicago, who were not feeble-minded, but were extremely retarded in arithmetic. The investigator states that tests of general intelligence were given, but does not share with the reader the exact results of such tests, saying only that the children "were not mentally defective." The result of tabulation of circumstances involved showed that ill-health and absence

were closely related to special disability in arithmetic. The inference is drawn that achievement in arithmetic calls for a hierarchy of *habits*, which depend on each other in a sequence. If a hiatus occurs at any essential point, as through absence, inattention, or inadequate teaching, confusion follows. (This inference seems very well justified, also, from the psychological analysis of the mental functions involved in arithmetic.) The problem of individual examination is to find out what habits have not been formed. The problem of pedagogy is to teach those habits, and to motivate the child.

Bronner's conclusion that some children of good intelligence lack the power to form number concepts is criticized by Schmitt. When the gaps in habit formation have been located, and the child has been motivated to form the missing habits, special deficiency in arithmetic disappears.

This is, on the whole, the conclusion to be drawn from the few studies which have included experimental teaching. Uhl studied a boy who could not subtract, according to standard tests. Analysis showed that he could subtract only by multiplying. For example, to subtract 9 from 46, he first set aside 1, to get a multiple of 9. Then he disintegrated 45 into 9's and dropped one of them. After disposing of the 9 in this devious fashion, he picked up his 1 again, and finally arrived at a correct result. It was thus found why he was so *slow*, and where instruction must be applied, in order to remedy the special deficiency which he showed in arithmetical calculation.

In difficult combinations, pupils invent interesting evasions. "Breaking up" larger numbers is common, so that $9 + 7 + 5$ becomes $9 + 2 + 2 + 2 + 1 + 2 + 2 + 1$, for instance.

Failure to form correct habits of interpreting symbols, or relations between symbols, often explains deficiency. This may be illustrated by the case of a girl who always read

$40 \overline{)1728}$ as "40 divided by 1728." Her results were thus fantastic. This error is analogous to that of writing "three dollars" as 3\$.

The remedy for these conditions is to show the child what he is doing, and to give drill until the correct and rapid method is thoroughly mastered. Special deficiency in the mechanics of arithmetic is to be improved by drill, after it has been found out where the drill is needed.

VI. METHODS OF DETECTING WRONG OR INCOMPLETE HABITS

Without systematic methods of testing, it would be a very difficult task to discover just what connections might be wrongly or inadequately formed, in the case of a given child. The standardized measuring scales and practice exercises, devised during the past fifteen years, furnish a systematic means of exploration. These are constantly being extended and improved, to cover each and every kind of habit that a child must acquire, for achievement in arithmetic.

The principle of these scales and tests is to establish by experiment the speed and accuracy of typical school children, grade after grade, in the performance of the various functions separately. It thus becomes possible to discover in the case of a deficient pupil whether he needs correction and drill in every function, or in only one function. By means of the Courtis tests, for example, it may be discovered whether a child's difficulty is in addition, multiplication, division, in speed or accuracy, or both speed and accuracy, and so forth.

The use of existing scales and tests for diagnostic purposes has been described by Courtis, Uhl, Anderson, and others. We may expect great improvement in these methods in the future. At present the standardizations are in terms of school grade norms. A better plan for diagnostic purposes

would be to standardize in age norms, giving a percentile distribution for each twelve-month interval of the period of immaturity.

VII. NERVOUS INSTABILITY AND SPECIAL DEFICIENCY IN ARITHMETIC

Nervously unstable children are, as Burt has pointed out, often deficient in arithmetic, even when in general intelligence they are not deficient. This follows from the same causes of failure as were set forth under discussion of nervous instability and special difficulty in reading. To build up little by little the intricate hierarchy of arithmetical habits, each habit in its essential sequence, is a task uncongenial to the flighty, uncontrolled, or negativistic neurotic.

Individual instruction is here, again, the solution of the problem. The neurotic can learn arithmetic within the limits of his intelligence, by means of patient individual instruction, given preferably at rather brief sittings.

VIII. ARITHMETICAL PRODIGIES

Extremely great ability to perform feats of mental arithmetic excites popular wonder and admiration to a degree far beyond that excited by most other manifestations of mental gifts. This may be due to the fact that in calculation each individual has a rather definite standard of performance, namely his own ability to calculate. When another goes far beyond him and his friends, in so definite a performance, he can see for himself that the typical has been phenomenally exceeded. The gifted person who exceeds the typical to an equal extent in perception of the fine shades of meaning in words, or in the detection of absurdities and contradictions in demagoguery, creates no sensation among his fellow townsmen ; for

there is no way whereby the average man can "check up" in the performances, to show himself how phenomenally he has been exceeded in capacity for them.

Bidder, the famous English calculator, is recorded in history because he could perform mental arithmetic perhaps fifty times as well as typical persons. The facts that he also became one of the most successful civil engineers of his time, and made a large fortune, are noted as of merely incidental interest, and would not have given him a place in the history of unusual persons. A man may make fifty times as much money as the average man does, by meeting with fifty times as much acumen and energy the intricate, subtle, and difficult situations offered by modern economic life. Yet he is not so very likely to be regarded as prodigiously gifted. His fellowmen can and will explain the difference between him and themselves as due to luck or circumstance. But a gift for "lightning calculation" is obviously peculiar to the person, and makes of him an object of wonder.

The same general considerations hold in the case of children. Many children of extraordinary intelligence are found, because they have attracted attention to themselves by excellence in arithmetic; and upon examination show themselves to be equally excellent at those tests which measure IQ, excellence in which is not necessarily conspicuous except to the trained psychologist.

Accounts of prodigious calculators go back to ancient Greece, in Lucian's reference to Nikomachos of Gerasa. The word "calculation" means literally "pebbling," coming from the Latin *calculi*, pebbles. Records of lightning calculators have been collected by Scripture and by Mitchell.

Jedediah Buxton (b. 1702) appears to be the first calculator on record in modern accounts. He lived at Elmton, England. "He labored hard with a spade to support a family, but seems

not to have shown even usual intelligence in regard to ordinary matters of life. . . . In regard to matters outside of arithmetic he appeared stupid." In 1754, when he was taken to London to be tested by the Royal Society, he went to see *King Richard III* performed. "During the dance he fixed his attention upon the number of steps; he attended to Mr. Garrick only to count the words he uttered. At the conclusion of the play, they asked him how he liked it. . . . He replied that such and such an actor went in and out so many times, and spoke so many words; another so many. . . . He returned to his village, and died poor and ignored." It is said that he could give an itemized account of all the free beer he had had from the age of 12 years.

Tom Fuller, "The Virginia Calculator" (b. 1710), seems to be another case of highly specialized ability. He came from Africa as a slave when about 14 years old. He is first heard of as a calculator at the age of 70 years, when it is stated that he reduced a year and a half to seconds in about two minutes, and 70 years, 17 days, 12 hours to seconds in about a minute and a half, correcting the result of his examiner, who had not taken leap years into the reckoning. He also calculated mentally the sum of a simple geometric progression, and multiplied mentally two numbers of nine figures each. He was totally illiterate.

Other prodigious calculators, who are not known to have had superior general ability, are Zerah Colburn (b. 1804), Henri Mondeux (b. 1826), Jacques Inaudi (b. 1867), and Ugo Zaneboni (b. 1867). None of these individuals achieved eminence in any other respect, but this does not necessarily prove that they were not of superior intelligence. It would have been impossible, for instance, for the slave, Tom Fuller, to achieve intellectual eminence in a profession.

None of them was studied psychologically except Inaudi,

who was examined by Binet. Inaudi was an Italian by birth. In childhood he tended sheep, as did Mondeux. His passion for numbers began at the age of about 6 years. At 7 years of age he could multiply five-place numbers by five-place numbers, "in his head." His memory-span for digits given orally was 42. He must hear them, the span being considerably reduced if he only saw them. He had little education, and did not learn to read and write until he was 20 years old. He lived by public exhibitions of his power to calculate. Binet concluded that he had no particular ability except the gift for calculation, and was not generally superior.

None of these calculators showed any gift for mathematics beyond arithmetic. Many others are on record who are known to have had great all-round superiority, and mathematical genius of the highest order, as is proven by their achievements. Bidder (b. 1806), Bidder, Jr. (b. 1837), Safford (b. 1836), Gauss (b. 1777), Ampère (b. 1775), Hamilton (b. 1788), and Whatley (b. 1787), all were lightning calculators.

George Parker Bidder was the son of a stonemason, of Devonshire. His family history is on record, and is quite interesting in connection with his gifts. His eldest brother, a Unitarian minister, had an extraordinary memory for Bible texts, but took no special interest in arithmetic. Another brother was an excellent mathematician and insurance actuary. Still other members of the family were distinguished in non-mathematical pursuits. Bidder's ability was first noticed when he was 6 years old. In 1822, at the age of 16 years, he took a prize in mathematics at the University of Edinburgh. He became a distinguished engineer, and accumulated wealth, as before stated. His son, the younger Bidder, was wrangler at Cambridge, and became barrister and Queen's counsel. He could multiply fifteen-place numbers by fifteen-place numbers, and could play two games of chess simultaneously,

blindfolded. Two of his daughters "showed more than average ability in mental arithmetic."

Truman Henry Safford was the son of a Vermont farmer, both parents having been school teachers. His power in calculation was noticed when he was 3 years old. At about 7 years of age, he began to study algebra and geometry, and soon thereafter, astronomy. In his tenth year he published an almanac, computed entirely by himself. His interests included chemistry, botany, philosophy, geography, and history in addition to astronomy and mathematics. He took his degree at Harvard in 1854, at the age of 18 years, and became an astronomer. He was professor of astronomy in Williams College for many years, until his death, and made many important astronomical calculations and discoveries.

Carl Frederick Gauss, the great mathematician, was a lightning calculator, the marvels of his performance exceeding those of nearly all others. Gauss entered the gymnasium when he was 11 years old, and in mathematics soon surpassed his teachers. He began the study of higher analysis at 10, and at 14 could read Newton with understanding. At 24 he published *Disquisitiones Arithmeticæ*, which is a fundamental contribution to mathematics. He himself has related that he remembers having followed by mental arithmetic a calculation concerning the wages of his father's workmen, and of having thus detected an error in the reckoning, at the age of 3 years. He could use from memory the first decimals of logarithms, and was especially ingenious at discovering new methods. Gauss was unquestionably a person of very extraordinary general intelligence. As a child he mastered not only mathematics, but also the classical languages with wonderful ease. It is quite possible, however, that his gift for mathematics exceeded his general capacity in other respects.

The renown of André Ampère's achievements in science is

commemorated in the ampère. As a child, he showed all-round ability, and encyclopedic interests. He learned counting at 3 or 4 years of age, by means of pebbles, "and was so fond of this diversion that he used for purposes of calculation pieces of a biscuit, given him after three days' strict diet." There is no question that Ampère was a child of extremely high IQ, the ability at calculation being but one manifestation of his great genius. He was a chemist, a metaphysician, and a mathematician. He became professor of mathematics, and wrote on probabilities, the unity of structure in organisms, and electrodynamics. In this last field he discovered fundamental truths, and immortalized his name. He was elected to the Academy of Sciences in Paris, and is recognized as one of the world's great thinkers, not as a calculator merely.

Richard Whatley, Archbishop of Dublin, was a prodigious calculator as a child. From 5 to 9 years of age he astonished onlookers by his feats. He afterwards ceased to interest himself in calculation, but used his intellectual capacity for achievement in other fields.

The greatest calculator on record, according to the researches of Scripture, is Johann Dase, born in Hamburg, in 1824. He could count objects with extreme rapidity. "With a single glance he could give the number, up to 30 and thereabouts, of peas in a handful, scattered on the table"; could give the number of sheep in a herd, or books in a case so quickly that his record remains unequaled. He could carry on enormous and protracted calculations, without recording figures, but seemed not to comprehend mathematical principles. He attended school when 2 to 3 years old, and began public exhibitions at 15 years of age. From the records it is not possible to prove or disprove superior general intelligence.

There are on record but three calculators, who were personally examined by psychologists, so far as the present writer

can learn. Inaudi, already mentioned, and Pericles Diamandi, a Greek grain merchant, born in 1868, were examined by Binet. Arthur Griffith, son of a stonemason, born in 1880, was examined by Lindley and Bryan, in the laboratory at the University of Indiana, in 1899.

Binet concluded that Inaudi had no unusual ability except for mental calculation, and that his auditory memory for digits was a special gift. Diamandi, on the other hand, in addition to his ability in calculation, knew five languages, was an incessant reader, and wrote both novels and poetry. He entered school at 7, and remained until he was 16, always heading his class in mathematics. His methods in calculation were visual. "He has a number-form of a common variety, running zig-zag from left to right, and giving most space to the smaller numbers. This number-form he sees as localized within a peculiar grayish figure, which also serves as a framework for any particular number or other object, which he visualizes."

Griffith had, from the age of 3, a passion for counting and made fair records in all studies. He entered school at 10, and attended school seven years. In scope and tenacity of memory, and in rapidity at calculation, he ranked with the best recorded cases, according to the investigators who examined him. Memory was described as very systematic; and rapidity was seen to depend on the great number of numerical relations committed to memory, and upon reduction in number of operations through short-cut methods.

These three examinations were all conducted more than twenty years ago, before standardized methods of measurement had been developed. It is difficult to glean from them, and from the biographical material compiled by Scripture and by Mitchell, what the truth is, as regards the extent to which this gift for calculation was special in these persons. Many of them, as we have seen, were certainly men of genius,

with general capacity for selective thinking. Several others probably were not of superior general intelligence, but in no case can we be certain, on the basis of anecdotal evidence alone. Some of them were peasants or slaves, born to manual toil, in the absence of free schools, and in the presence of rigid class distinctions. It is not inconceivable that a child of IQ over 170, condemned by unavoidable environment to herd sheep or pick cotton through his youth, might find relief from the monotony of his work by calculating. As Mitchell, himself a lightning calculator, says, "Given a knowledge of how to count, and later a few definitions, and any child of average ability can go on, once his interest is accidentally aroused, and construct, unaided, practically the whole science of arithmetic, no matter how much or how little he knows of other things." This statement is probably true, if we change one word, and substitute for "child of average ability," "child of great ability."

All who have examined lightning calculators, or searched their biographical records, are agreed that the secret of their power lies in highly developed mechanics. Special *habits* of combining and recognizing numbers are formed, which differ from ordinary calculation comparatively in somewhat the same way as the method of the child who added $7+5$ by adding $7+2+2+1$, the latter being analogous to the usual method.

The lightning calculator memorizes combinations far beyond those ordinarily memorized, so that he is, for instance, able to add $2581+1763$ as quickly as an ordinary person can add $15+8$. He learns multiplication tables up to 100×100 , whereas we learn only through 12×12 . He devises and uses many "short cuts," *e.g.* multiplying by two easy numbers and taking the difference, instead of multiplying by an awkward number. Multiplication is probably used as the fundamental operation.

This specialization in and perfection of arithmetical connections, by a person of original aptitude for and interest in numbers, results in the prodigious calculator. As Scripture concludes, "These persons had enormous ability to learn calculation, not to calculate without learning." The rôle played by practice is seen in the fact that if interest in counting wanes, and practice at calculation ceases, the skill acquired deteriorates through disuse. Whatley, and others, who became distracted from calculation by other interests as they grew up, lost the power they had possessed. However, by resuming practice, the skill can be regained by those who have acquired it, as is the case with skills in general.

Satisfaction in mental activity for its own sake is expressed by those calculators who have given introspections. After Safford had lost the power of lightning calculation through disuse, he continued to take pleasure in factoring large numbers, or in satisfying himself that they were prime. The younger Bidder said, "With my father, as with myself, the handling of numbers or playing with figures afforded a positive pleasure, and constant occupation of leisure moments. Even up to the last year of his life,¹ my father took delight in working out long and difficult arithmetical and geometrical problems."

All who have studied material relating to prodigious calculators have especially stressed the very early age at which the gift has shown itself. This is especially true of those who achieved greatness in science, as adults. Gauss, Whatley, and Ampère were all first noted at the age of 3 years, and Safford and Bidder at the age of 6 years. It appears to the present writer to be probable that any child of IQ over 180 could be taught to be a lightning calculator. This inference comes from observing such children, as they master numbers.

¹ Bidder died at 72.

IX. ARITHMETICAL ABILITY OF TWO CHILDREN OF IQ 184
AND IQ 187 (STANFORD-BINET)

To illustrate mathematical aptitude in children of high IQ, a brief account is herewith given of two boys, both known professionally to the present writer since early childhood. These children are both of a degree of general intelligence so rare as to be scarcely ever found, and both are especially interested in mathematics.

The boy D, of IQ 184, was described first by Terman, in *The Intelligence of School Children*. His achievements are most remarkable in every kind of intellectual activity, including music and drawing. Among his favorite pastimes since infancy has been the manipulation of numbers. His calculations, dating from the time his hand could wield a pencil, have covered hundreds of pages. As a child of 7, 8, and 9 years, D found the keenest satisfaction in deriving formulæ to render himself unbeatable at family games based on number. At the age of 12 years he has completed the mathematical curriculum of the elementary and secondary schools, through arithmetic, algebra, geometry, and trigonometry. (It should be added that he has also completed the curriculum of the elementary and secondary schools in all other respects, and is ready at 12 years to enter college.)

Figure 15 shows D's calculations on Test 2, of Army Alpha, Form 5, five minutes being allowed for the performance. Figure 16 shows his calculations on Test 6, of the same form of Alpha, three minutes being allowed. D was 10 years 11 months old on the date of these calculations. He had never previously seen either of these tests.

The second child to whom we wish to refer briefly is R, of IQ 187. He, too, has delighted in number from about the third year of life. When first seen by the present writer, at

TEST 2

Get the answers to these examples as quickly as you can.

Use the side of this page to figure on if you need to.

- SAMPLES { 1 How many are 5 men and 10 men?.....Answer (15)
 2 If you walk 4 miles an hour for 3 hours, how far
 do you walk?.....Answer (12)
- 1 How many are 30 men and 7 men?.....Answer (37)
 2 If you save \$7 a month for 4 months, how much will you save?
 Answer (28)
- 3 If 24 men are divided into squads of 8, how many squads will
 there be.....Answer (3)
 4 Mike had 12 cigars. He bought 3 more, and then smoked 6.
 How many cigars did he have left?.....Answer (9)
 5 A company advanced 5 miles and retreated 3 miles. How far
 was it then from its first position?.....Answer (+ 2)
- 6 How many hours will it take a truck to go 66 miles at the
 rate of 6 miles an hour?.....Answer (11)
 7 How many cigars can you buy for 50 cents at the rate of 2 for
 5 cents?.....Answer (20)
 8 A regiment marched 40 miles in five days. The first day they
 marched 9 miles, the second day 6 miles, the third 10 miles,
 the fourth 8 miles. How many miles did they march the last
 day?.....Answer (7)
 9 If you buy two packages of tobacco at 7 cents each and a pipe
 for 65 cents, how much change should you get from a two-
 dollar bill?.....Answer (\$1.21)
 10 If it takes 6 men 3 days to dig a 180-foot drain, how many men
 are needed to dig it in half a day?.....Answer (36)
- 11 A dealer bought some mules for \$800. He sold them for \$1,000,
 making \$40 on each mule. How many mules were there?..Answer (5)
 12 A rectangular bin holds 400 cubic feet of lime. If the bin is
 10 feet long and 5 feet wide, how deep is it?.....Answer (8)
 13 A recruit spent one-eighth of his spare change for post cards
 and four times as much for a box of letter paper, and then had
 90 cents left. How much money did he have at first?...Answer ()
 14 If $3\frac{1}{2}$ tons of coal cost \$21, what will $5\frac{1}{2}$ tons cost?....Answer (33)
 15 A ship has provisions to last her crew of 500 men 6 months.
 How long would it last 1,200 men.....Answer (14 $\frac{2}{3}$)
- 16 If a man runs a hundred yards in 10 seconds, how many feet
 does he run in a fifth of a second?.....Answer (6)
 17 A U-boat makes 8 miles an hour under water and 15 miles on
 the surface. How long will it take to cross a 100-mile channel,
 if it has to go two-fifths of the way under water?....Answer (~~8~~ 10)
 18 If 241 squads of men are to dig 4,097 yards of trench, how
 many yards must be dug by each squad?.....Answer (~~17~~ 17)
 19 A certain division contains 3,000 artillery, 15,000 infantry and
 1,000 cavalry. If each branch is expanded proportionately
 until there are in all 20,900 men, how many will be added to
 the artillery?.....Answer ()
 20 A commission house which had already supplied 1,897 barrels
 of apples to a cantonment delivered the remainder of its stock
 to 29 mess halls. Of this remainder each mess hall received 54
 barrels. What was the total number of barrels supplied?..Answer ()

$$3:12=6:x$$

$$72=3x$$

$$300:10=x:5$$

8

FIG. 15. — Showing D's calculations on Test 2, Army Alpha, Form 5, at the age of 10 years 11 months, five minutes being allowed for the performance. The only figuring done on paper appears in the margin.

TEST 6

SAMPLES	{	2	4	6	8	10	12	<u>14</u>	<u>16</u>
		9	8	7	6	5	4	<u>3</u>	<u>2</u>
		2	2	3	3	4	4	<u>5</u>	<u>5</u>
		1	7	2	7	3	7	<u>4</u>	<u>7</u>

Look at each row of numbers below, and on the two dotted lines write the two numbers that should come next.

3	4	5	6	7	8	.9...	.10.
10	15	20	25	30	35	.40.	.45
8	7	6	5	4	3	.2...	.1...
3	6	9	12	15	18	.21..	.24
5	9	13	17	21	25	.29..	.33.
8	1	6	1	4	1	.2...	.1...
27	27	23	23	19	19	.15..	.15.
1	2	4	8	16	32	.64..	.128
8	9	12	13	16	17	.20...	.21.
9	9	7	7	5	5	.3....	.3...
19	16	14	11	9	6	.3...	.0...
2	3	5	8	12	17	.23..	.30.
11	13	12	14	13	15	.14..	.16.
29	28	26	23	19	14	..8.	..1..
18	14	17	13	16	12	.15..	.11.
81	27	9	3	1	$\frac{1}{3}$	.19.	.127
20	17	15	14	11	9	..8..	..5..
16	17	15	18	14	19	.13..	.20
1	4	9	16	25	36	.49.	.64
3	6	8	16	18	36	.....	.....

FIG. 16. — Showing D's calculations on Test 6, Army Alpha, Form 5, at the age of 10 years 11 months, three minutes being allowed for the performance.

the age of 6 years 6 months, R's memory span for digits was at least eight (beyond this he was not tested), and he could easily reverse seven digits at least (beyond this the test did not go). He has been taught short cuts and other mechanics of lightning calculation till now, at the age of 8, he can with great speed calculate the answer to such a series as " $2 \times 2 \times 2 \times 2$ multiplied by twice the square of 2; square it," or " $2255^2 - 2245^2$."

In Figure 17 is shown R's calculation on Test 2, Army Alpha, Form 5, and in Figure 18, his performance in Test 6, the time limits being the same as indicated for D. R was 7 years 6 months old on the date of these performances. The ordinary child of that age can, of course, make no score whatever. R had never previously seen either of the tests.

R's teacher¹ writes of him, "His ability in academic work seems well distributed, though strongest in mathematics. For this grade he is remarkably low in art and industrial work, but he would be average in the second grade, where his age would usually place him. His artistic feeling is all for music and literature. . . . I think he is rather clumsy with his hands even for his age, though not much below the average child. With his mental ability he can learn to do anything in which his interest is aroused. . . . As he goes on, I hope that we can arrange for him to work with more advanced groups in mathematics and science, though remaining in the present group for most of the day. . . . In mathematics it is noticeable that although he can use short cuts which are Greek to the class, he is quite as apt to make an error in concrete problems as the other bright children. This is not lack of attention or interest, for he is always keenly alive in any lesson in mathematics. For example, in shop where he was making a table

¹ The writer is indebted to Miss Mabel R. Goodlander, R's teacher in the fourth grade, for this report.

TEST 2

Get the answers to these examples as quickly as you can.
Use the side of this page to figure on if you need to.

- SAMPLES { 1 How many are 5 men and 10 men?.....Answer (15)
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do you walk?.....Answer (12)
- 1 How many are 30 men and 7 men?.....Answer (37)
2 If you save \$7 a month for 4 months, how much will you save?
Answer (\$28)
- 3 If 24 men are divided into squads of 8, how many squads will
there be?.....Answer (3)
4 Mike had 12 cigars. He bought 3 more, and then smoked 6.
How many cigars did he have left?.....Answer (9)
5 A company advanced 5 miles and retreated 3 miles. How far
was it then from its first position?.....Answer (2 miles)
- 6 How many hours will it take a truck to go 66 miles at the
rate of 6 miles an hour?.....Answer (11)
7 How many cigars can you buy for 50 cents at the rate of 2 for
5 cents?.....Answer (20)
- 8 A regiment marched 40 miles in five days. The first day they
marched 9 miles, the second day 6 miles, the third 10 miles,
the fourth 8 miles. How many miles did they march the last
day?.....Answer (7)
- 9 If you buy two packages of tobacco at 7 cents each and a pipe
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dollar bill?.....Answer (\$1.21)
- 10 If it takes 6 men 3 days to dig a 180-foot drain, how many men
are needed to dig it in half a day?.....Answer (36 men)
- 11 A dealer bought some mules for \$800. He sold them for \$1,000,
making \$40 on each mule. How many mules were there?.....Answer (25)
- 12 A rectangular bin holds 400 cubic feet of lime. If the bin is
10 feet long and 5 feet wide, how deep is it?.....Answer ()
- 13 A recruit spent one-eighth of his spare change for post cards
and four times as much for a box of letter paper, and then had
90 cents left. How much money did he have at first?....Answer ()
- 14 If $3\frac{1}{2}$ tons of coal cost \$21, what will $5\frac{1}{2}$ tons cost?....Answer ()
- 15 A ship has provisions to last her crew of 500 men 6 months.
How long would it last 1,200 men?.....Answer ()
- 16 If a man runs a hundred yards in 10 seconds, how many feet
does he run in a fifth of a second?.....Answer ()
- 17 A U-boat makes 8 miles an hour under water and 15 miles on
the surface. How long will it take to cross a 100-mile channel,
if it has to go two-fifths of the way under water?.....Answer ()
- 18 If 241 squads of men are to dig 4,097 yards of trench, how
many yards must be dug by each squad?.....Answer ()
- 19 A certain division contains 3,000 artillery, 15,000 infantry and
1,000 cavalry. If each branch is expanded proportionately
until there are in all 20,900 men, how many will be added to
the artillery?.....Answer ()
- 20 A commission house which had already supplied 1,897 barrels
of apples to a cantonment delivered the remainder of its stock
to 29 mess halls. Of this remainder each mess hall received 54
barrels. What was the total number of barrels supplied?..Answer ()

$$\begin{array}{r} 200 \\ 79 \\ \hline 1.21 \end{array}$$

$$\begin{array}{r} 25 \\ 40 \overline{)1000} \\ 200 \end{array}$$

FIG. 17. — Showing R's calculation on Test 2, Army Alpha, Form 5, at the age of 7 years 6 months, five minutes being allowed for the performance. Note immature formation of the numerals. The only part of the figuring done on paper appears in the margin.

TEST 6

SAMPLES	{	2	4	6	8	10	12	14	16
		9	8	7	6	5	4	3	2
		2	2	3	3	4	4	5	5
		1	7	2	7	3	7	4	7

Look at each row of numbers below, and on the two dotted lines write the two numbers that should come next.

3	4	5	6	7	8	.9..	.10.
10	15	20	25	30	35	.40.	.45.
8	7	6	5	4	3	.2..	.1..
3	6	9	12	15	18	.21.	.24.
5	9	13	17	21	25	.29.	.33.
8	1	6	1	4	1	.2..	.1..
27	27	23	23	19	19	.15.	.15.
1	2	4	8	16	32	.....	.....
8	9	12	13	16	17	.20.	.21.
9	9	7	7	5	5	.3..	.3..
19	16	14	11	9	6	.....	.....
2	3	5	8	12	17	.23.	.30.
11	13	12	14	13	15	.16.	.17.
29	28	26	23	19	14	.8..	.1..
18	14	17	13	16	12	.....	.....
81	27	9	3	1	1/3	.....	.....
20	17	15	14	11	9	.....	.....
16	17	15	18	14	19	.....	.....
1	4	9	16	25	36	.....	.....
3	6	8	16	18	36	.....	.....

FIG. 18. — Showing R's calculation on Test 6, Army Alpha, Form 5, at the age of 7 years 6 months, three minutes being allowed for the performance. Note immature formation of the numerals.

with a top 24 inches square, he was shown the lumber (12 inches wide) and asked how many pieces he must prepare for the table. He replied 'three,' and it was some time before he was led to recognize his mistake."

With his love of mathematics, R combines a passion for classifying. As early as his first year of life, he would classify his playing blocks according to the shape of the letters on them, — O, Q, P, and the like together, and A, V, W, N, M, and the like in another group, and so forth. This delight in classifying is also one of D's most conspicuous characteristics.

X. THE INHERITANCE OF ARITHMETICAL ABILITIES

From his search through the literature pertaining to arithmetical prodigies, Mitchell concluded that he could not find sufficient data from which to generalize concerning heredity. This conclusion is no doubt justified. We must wait upon modern studies, in order to gain knowledge of the extent to which such tendencies may be inherited. We may note, however, that many relatives, gifted in some way, are reported among the lightning calculators of history. Diamandi's mother "had an excellent memory for all sorts of things," and a brother and a sister out of a family of fourteen siblings shared his aptitude for mental arithmetic; the family history of the Bidders has been referred to already; Safford's father and mother were both teachers; Gauss had a maternal uncle of known mechanical and mathematical talent; Mitchell's younger brother could play chess blindfolded. Of the two children, D and R, herein described, both have many adult relatives who are or were writers, money-makers, inventors, or organizers. Of this generation, D is an only child, but he has several cousins. Of these, three who have been measured show IQ's of 150, 156, and 157, respectively. R's

only brother has an IQ of 150, and of his two cousins, both girls, the only one yet measured has an IQ of 170. These are suggestive fragments of facts concerning family resemblances.

Cobb has made a quantitative study of resemblance between parents and children, in the various fundamental processes, using five of Courtis' standard tests. She finds that the coefficient of correlation between child and like parent is .60, between child and unlike parent, .01, between child and mid-parent, .49. By "mid-parent" is meant the ability that falls midway between the abilities of the two parents. Twenty persons were studied in eight families. No sex differences were noted. A child of either sex may resemble either parent, and not all children of the same family do resemble the same parent. Cobb concludes that the likeness found is due to heredity.

In the matter of sex differences, it is notable that of all the lightning calculators recorded only one, and she of minor importance, was of the female sex. It is possible that this difference may be due to native sex differences in the inheritance of endowment. It is much more probably due, however, to those differential pressures — social, educational, and economic — which cast up to public notice more deviates of all kinds among the male sex. During the periods from which the records of lightning calculators have been gathered, this differential pressure was much more forceful than it is now. Because of the differential action upon the sexes of social pressures, it is never possible to make valid comparisons of the sexes in respect to mental deviation, unless the sampling has been rigidly made in some manner absolutely indifferent to selection, and unless the measurements have been objectively taken.

XI. IMPLICATIONS FOR EDUCATION

Studies thus far made would convince us that arithmetical skill consists in the automatization and integration of a hierarchy of habits, which can be acquired to a passable degree by all children of average intelligence. Lightning calculation results from building up and rendering automatic still further habits, and can be achieved by persons of great general intelligence. It remains an open question whether a generally stupid person can ever become a prodigious calculator, but it seems certain that interest in and aptitude for arithmetic may be especially marked in generally superior children.

Arithmetical ability may develop, without simultaneous development of ability in other branches of mathematics. One may calculate prodigiously, without comprehending algebraic and geometric principles, or being interested in them. Also one may be more or less adept, either by nature or by training, in one kind of arithmetical function than in others.

Drill is the means for improving arithmetical ability, so far as speed and accuracy of calculation are concerned. Ability in problem solving can probably not be much affected by drill, since "a problem" is, by definition, something that requires independent adjustment, and not the response of automatic habit. It therefore calls on general intelligence, and cannot be improved after the mechanics of reading and calculating have been mastered up to the limits of capacity.

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CHAPTER VII

DRAWING

I. THE VARIOUS KINDS OF DRAWING

MANUEL, who has made a careful psychological study of talent in drawing, defines drawing as follows: "The term *drawing* designates a process of causing, by means of pencil, pen, brush, or other instrument, certain lines or areas, or both, to appear on a given surface." This definition we may accept, if we add that the lines and areas are intended or can be interpreted to signify something. We should not agree, for instance, that the lines and areas which are caused to appear on the ground by the scratching of a fowl should be included within the definition.

Having been thus defined, drawings may be classified into many kinds, in accordance with the technique employed and the meaning conveyed. These kinds are (1) copying, (2) representative drawing, (3) analytical or diagrammatic drawing, (4) impressionistic drawing, (5) symbolic drawing, and (6) caricature. This classification is exclusive of other forms of graphic or representative expression, such as painting, sculpture, and paper-cutting (used in the art of cutting silhouettes).

These various kinds of presentations differ as to the psychophysical equipment constituting talent for them. It is therefore impossible, as psychological study has proved, to discuss talent for drawing, without specifying what kind of drawing is under consideration. Talent for painting, sculpture, and

cutting silhouettes has been little studied, so that we are not in position to discuss these at the present time, either as processes in themselves or as related to drawing.

The term *copying* is self-explanatory. By *representative drawing* is meant a drawing having visual realism, which "looks like" that from which it is drawn. *Analytical (diagrammatic) drawing* is logical. It may violate features essential to visual realism, stressing only aspects from certain points of view, or abstracting a general principle. For instance, the plan for the ground-floor of a house, or a schema of arterial circulation, would be analytical. *Mechanical drawing* comes under this category, as does also, in a sense, *conventionalized drawing*, for in conventionalized drawing some general principle or pattern is abstracted from concrete instances, and is made the basis of the design. A conventionalized bird does not look like any particular bird ever seen by anyone, but, on the other hand, it looks like all birds. It is a non-existent, composite, typical bird. *Impressionistic drawing* conveys an idea without much attention to visual realism. A curve stands for a cloud, two vertical lines suggest trees, a few zig-zag marks indicate grass and flowers. In *symbolic drawing* one thing is drawn to represent another thing, as a crown is drawn to represent royalty. Symbolic drawing does not, perhaps, deserve separate classification, in a study of abilities, but for the present it seems best to differentiate it. To originate symbolic drawings may call for capacities not included in the other forms of graphic presentation. Finally, *caricature* is drawing that catches and exaggerates individual peculiarities, most often with a result which is humorous or satirical. The art of cartooning depends very largely on caricature and symbolism for its effect. Cartoons interpret life. The successful cartoonist, therefore, combines talent for drawing with a high degree of general intelligence.

II. RAMIFICATIONS OF DRAWING THROUGH THE CURRICULUM

When we speak of drawing in the schools, there is a tendency to think only of those performances which are taught and executed during the time set aside for instruction by the teacher of drawing. But a little reflection will show us to what an extent drawing ramifies through the curriculum, and forms an element in achievement.

In geography map-drawing is required. In nature study, notebooks with drawings of natural objects seen are frequently kept. In sciences taught by the laboratory method drawing is an important element in success. Zoölogy, physiology, and botany are especially taught through drawing. In mechanics, and in engineering, drawing plays a prominent part. Thus it comes about that school marks in all these subjects depend to some extent on drawing of some kind. If psychological study shows capacity for drawing to be largely or utterly dissociated from general intelligence, the use of drawing to so great an extent, as a method of recitation in the sciences especially, may be undesirable. The belief that drawing used in this way fails to meet the need of many pupils, otherwise apt in science, led Ayer to undertake the interesting investigation to which it will be necessary to give our attention in detail, throughout this chapter.

III. PSYCHOLOGICAL ANALYSIS OF TALENT IN DRAWING

It is quite interesting to notice that the analysis of ability in reading, spelling, and arithmetic has been approached largely through studies of the particularly deficient, while in the case of drawing and music the approach has been through study of the gifted, to a greater extent.

The psychographic study of individual talent in drawing

was preceded by many investigations of what children draw, at what ages various details appear in drawings, how the drawings of one group compare with those of another, and what people say about the drawings they make. These studies, up to 1915, have been brought together by Ayer, and are so well summarized by him in relation to the study of aptitude, that there is no need to summarize them again. Those who desire to become familiar with the whole literature of the psychology of drawing will do well to consult Ayer's work.

Several analyses of ability to draw have been undertaken, some through study of the particularly deficient, some through study of the conspicuously talented. Meumann thus states the causes of inefficiency in drawing :

(1) The will to analyze and to notice forms and colors has not been stimulated.

(2) The intention to analyze may be aroused, and yet the individual may find the analysis too difficult. This is a matter of innate talent.

(3) The memory of that to be represented may be deficient. It may be incomplete or vague in form or in color. The memory of spatial relations may be inadequate. This, too, is a matter of innate talent.

(4) There may be lack of ability to hold the image during the act of drawing. This capacity is innate.

(5) The memory image and the perceptual image may not be coördinated with the movements in drawing. This capacity is innate.

(6) The sight of the drawing in its imperfection as compared with the memory image may disturb the image.

(7) The drawer may lack schemata on which to found his drawing.

(8) There may be failure to comprehend how one may project space in three dimensions upon a plane.

(9) Manual skill may fail.

(10) There may be no artistic sense.

(11) Inability to draw may arise from a combination of various of these deficiencies.

Manuel has offered the following analysis, after study of persons especially talented :

The following characteristics, each an independent or partially independent variable, seem closely related to ability in drawing:

- (1) The ability mentally to note a visual form, and, by certain lines and areas, to reproduce it or significant features of it.
- (2) Ability to observe.
- (3) Ability to select from a complex visual situation the most representative and the most beautiful aspects.
- (4) Memory for visual forms.
- (5) Ability mentally to manipulate visual forms.
- (6) Ability to control hand movements in accordance with visual percept or image.
- (7) Ability to invent, to bring together into new artistic combinations the elements of different visual experiences.
- (8) Ability to judge the beautiful in line, form, color, and composition.
- (9) Ability to discriminate differences in color.
- (10) Ability to discriminate differences in visual magnitude.
- (11) Acuity of vision.
- (12) Interest in the act and products of drawing.
- (13) General intelligence.

These two analyses may serve as samples, since they include practically all the elements suggested by any other investigators. Jones has recently furnished us with additional evidence that memory of objects visually perceived and perception of perspective are probably important contributors to drawing ability. Among 264 school children in the seventh and eighth grades of the Evanston public schools, a correlation was found of .83 between visual memory and ability to draw. Perception of perspective and visual memory yielded a coefficient of .85.

As a result of administering more than twenty tests to 19 individuals gifted in drawing, Manuel concludes that, "Persons talented in drawing exhibit great individual differences in their psychophysical characteristics." Nevertheless, tests devised to measure status in the traits listed in the analyses

which have been made, would be expected to yield, finally, a psychograph of talent in each of the various kinds of drawing. Persons approximating these psychographs could then be identified as talented in drawing, and those deviating widely from them could be classified as deficient in ability to draw. The invention and standardization of such tests is a matter for further research. At present we have no means of gauging talent in drawing except by grading a finished product on a scale of drawings, like Thorndike's "Scale for Measuring Achievement in Drawing." Such a means does not always adequately separate talent from training.

The hope that psychographs of ability to draw may be platted in future does not mean that psychologists expect to find complete similarity among those talented in drawing. Individuality is as intrinsic in drawing as it is in handwriting. As a signature can be used for identification in the hands of experts, so a picture bears the mark of the particular psychophysical constitution that produced it. The ordinary reader of current fiction knows, by inspection, whether a given illustration has been made by May Wilson Preston or by Tony Sarg, without seeing the signature. The drawings of Clarence Day are inimitable.

IV. RELATIONS BETWEEN APTITUDE IN DRAWING AND GENERAL INTELLIGENCE

As long ago as 1903, Fischlovitz studied 350 high school freshmen, to obtain the correlation between ability to draw and ability in other high school studies. Correlations were computed between grades in drawing and in other subjects. The conclusion was that, "Ability in drawing is correlated to a greater degree with some of the subjects than with others, but in no case is the correlation very strong, and that ability in drawing is more of a special ability."

Some years later, Elderton obtained a correlation of .416 between grades in drawing and grades in classics, for one class, and of $-.313$ between the grades in the same studies, in another class. The subjects were here 19 boys in each of two classes in an English public school. Ivanof found among Swiss children a tendency for the able in drawing to include somewhat more good all-round pupils than were included among the pupils at large, and an opposite tendency among those poor in drawing. The figures show, however, many pupils strong in general work listed among those poor in drawing. Ayer obtained a correlation of .66 between grades in drawing and other subjects, for 141 normal school students.

As Ayer points out, these methods are very crude as means of determining to what extent drawing is a special ability. In the first place, since drawing is used as a form of recitation in various school subjects, we are obtaining to some extent a self-correlation in subjects like science and geography. In the second place, grades in drawing do not specify *what kind* of drawing is graded. In the case of Ayer's normal school students, special inquiry showed that the grades in drawing were computed from heterogeneous factors, including (a) ability in representative drawing, (b) ability in designing, (c) ability in artistic discrimination, (d) ability with color, washes, shading, etc., (e) attendance, (f) discipline, (g) vocational interest. School marks do not, therefore, isolate ability in any one kind of drawing, from a medley of other relevant and irrelevant factors, the mark being bestowed upon the total composite of factors.

Much more reliable as a method of research is the method of tests. In Simpson's data, already quoted, it is seen that drawing lengths shows very slight coherence with other abilities. Other similar fragmentary suggestive facts may be

found, scattered through the literature. In 1916 Ayer undertook a well-planned investigation to determine how two kinds of drawing, (1) representative drawing and (2) analytical drawing, are related to (a) ability in verbal description and (b) achievement in school subjects on the whole.

A turkey feather was drawn representatively, drawn analytically, and described verbally by 51 high school pupils. Twenty-four hours after the analytical drawing, the pupils were again required to make a diagram of the feather and to answer questions about its parts. The results of these various efforts were then scored by ten competent judges independently, to obtain a final score for each pupil in each test.

The table, from Ayer, on page 149, shows the rank obtained by each pupil in each kind of performance. The pupil who stands first in memory stands thirty-eighth in representative drawing, and so forth down the series, for each pupil.

In the following table, from Ayer, we see the coefficients of correlation found between the various functions tested, as computed from the ranks listed in the table on page 149.

TABLE FROM AYER

Showing correlations in case of representative drawing, retention, diagramming (analytical drawing), and description.

ABILITIES CORRELATED	COEFFICIENT OF CORRELATION (PEARSON)
Representative drawing and description . . . . .	.023
Diagramming and representative drawing	— .052
Diagramming and description . . . . .	.231
Representative drawing and retention	— .022
Description and retention . . . . .	.234
Analytical drawing and retention . . . . .	.433

TABLE FROM AYER

Rank in retention, representative drawing, description, and analytical drawing, as tested in the case of 51 students in a first year high school class in general science.

RANK IN MEMORY	RANK IN DRAWING	RANK IN DE- SCRIPTION	RANK IN DIAGRAM	RANK IN MEMORY	RANK IN DRAWING	RANK IN DE- SCRIPTION	RANK IN DIAGRAM
1	38	2	1	27	6	32	47
2	41	14	5	28	16	34	18
3	37	1	14	29	20	31	8
4	22	30	41	30	4	50	22
5	7	46	4	31	44	18	40
6	17	20	10	32	19	4	17
7	48	22	43	33	13	48	45
8	27	19	6	34	33	16	33
9	42	6	27	35	11	8	44
10	39	9	31	36	23	47	36
11	31	44	19	37	1	43	38
12	36	10	9	38	43	33	29
13	18	41	26	39	8	36	11
14	21	29	12	40	29	42	21
15	9	38	23	41	30	3	46
16	35	13	35	42	2	26	42
17	51	37	24	43	47	28	28
18	25	35	39	44	32	21	7
19	10	24	34	45	15	27	20
20	26	5	25	46	46	39	47
21	12	17	30	47	49	11	16
22	28	49	51	48	50	40	50
23	34	25	13	49	5	45	30
24	3	12	15	50	40	23	48
25	45	45	3	51	14	51	49
26	24	7	2				

The correlation between representative drawing and verbal description is practically zero. From knowledge of ability in one of these functions, among high school students, no inference can be made concerning the other. Ability in diagramming (a kind of analytical drawing) is also not correlated with representative drawing. On the other hand, the

processes of diagramming and description exhibit a slight tendency to positive coherence, as do description and retention. Analytical drawing and retention have a decided tendency to cohere, with a coefficient of .433.

In order to check his finding that school marks in drawing correlate well with school marks in other subjects, Ayer correlated the scores of these 51 high school pupils in *representative drawing*, with their school marks and found an absence of relationship. "Ability in representative drawing is not correlated with achievement in school subjects, when it is isolated from the other factors of school drawing."

Ayer concludes that different kinds of drawing are differently correlated with general intelligence, and that it is necessary to isolate the various kinds in determining the relationship. Analytical drawing is a better indication of a pupil's general grasp of subject matter than is representative drawing. He recommends "that the device of representative drawing shall be supplanted in laboratory teaching," since it appears to be a highly specialized function.

The question of the relationship between general intelligence and ability to draw has also been investigated by Manuel, who took the IQ of each of his talented subjects by means of Stanford-Binet. These were pupils in elementary school, high school, and college. This means of measuring general intelligence was ill adapted to its purpose in the case of the college students and, also, probably in the case of many of the high school students among his subjects, as the scale will not measure the intelligence of very superior adolescents and adults. Because of its limitations, the most intelligent adult in the world cannot show an IQ of more than about 120 on it. Therefore some of Manuel's older subjects may have been much more intelligent than appears on the record. The range of intelligence among those talented in drawing may be even

greater than the record shows. The tests as they stand show that superior ability in drawing may accompany any degree of general intelligence from very superior to very inferior. "We conclude therefore that a certain elementary ability in graphic representation, such as is required for success in elementary school drawing, is independent, or partially independent, of general intelligence."

It should be stated that presence of talent in drawing in the case of these individuals was determined in part by testimony of teachers of art, and in part by two tests, (1) the drawing of a house from memory, and (2) the drawing of a wooden cart from the object. Both of these would be classified as *representative drawings*.

Where representative drawing has been isolated for study in relation to general intelligence, no results contradictory to the conclusions stated above have been reported. Earlier investigators had declared that great talent for graphic expression is closely connected with good intellectual endowment in children, but that "the reverse of this does not hold true." This conclusion will probably be shown to be well founded in future researches carried out by modern test methods. "Great talent" includes much more than mere ability to "see and make" an object. As Manuel says, "Before one gets very far in art expression, a great number of supplementary factors must be brought to the support of the ability to represent graphically simple objects. Even the technique itself becomes progressively more difficult. . . . General intelligence conditions the ability of drawers (a) to acquire the advanced technique into which conceptual factors enter, and (b) to create original drawings of merit."

Manuel also gave tests of linguistic ability in the course of his study and found no essential relationship between ability to draw and ability to manage words. "Linguistic ability is

no index of ability or lack of ability in graphic representation," but linguistic ability correlates well with general intelligence (as has been previously emphasized in this volume).

For purposes of educational and vocational guidance we now need especially studies of the relationship between general intelligence and kinds of drawing other than the representative. We require studies of the extent to which copying, analytical drawing, symbolic drawing, and caricature are correlated with general mental capacity. It may be predicted with some confidence that research in unselected groups will finally show copying and representative drawing to be slightly correlated with general intelligence. Analytical and symbolic drawing are probably significantly correlated with general intelligence, while caricature is doubtless very closely correlated with intellectual capacity.

We need also researches bearing upon the relationship between ability in painting, sculpture, and pattern-cutting, and general intelligence. To what extent are painters and sculptors of high repute also gifted with superior intellectual acumen? Popular opinion would have it that the "artistic mind" is antagonistic in its organization to the "scientific mind." Probably here as elsewhere uncontrolled speculation leads to false conclusions. Probably those who achieve eminence in the arts are, on the whole, as highly endowed with general intelligence as are those who win eminence in other kinds of careers. Greatness in graphic portrayal almost certainly results only when there is a rare combination of highly specialized capacity for representative drawing, and very high IQ, in the same individual.

Fortunately for all, modern life calls for all forms of talent in drawing, in all degrees of combination with general intelligence. Sign painters, copyists, designers, draughtsmen, architects, illustrators, and creative interpreters of human faces

and of human life are all needed. Persons skilled in drawing are essential to mechanical and industrial development in society, for everything made must first be drawn, from the motor of an airplane to the fancy buttons on a child's coat.

V. THE COLOR-BLIND

Between 3 and 5 per cent of boys, and apparently fewer girls, inherit a special defect of vision, called "color blindness." A color-blind child may be gifted in drawing, except in color drawing, but he will be incompetent as a painter.

There are several forms of this special defect. Very rarely it may happen that no discrimination among colors is possible, the world appearing, as in a photograph, to consist only of light and shade. In the late evening, or in any sufficient dimness, color is not perceived by ordinary eyes. Those who are blind to all colors do not see color with the brightening of the light, as ordinarily happens.

The most common form of color blindness is, however, that in which only red-green sensations are absent, other colors being distinguishable. There is no disease present in such cases. The defect is hereditary, and consists in deviation from the typical in structure of the retina. The eyes of color-blind persons are as healthy and normal as those of others, in respect to functions other than acting as receptors for certain waves of light.

A few cases of blue-yellow color blindness have been reported, these resulting from pathological causes.

A color-blind child does not, of course, know from his own experience that he is so. He supposes that everyone sees what he sees, until informed by test or disaster of his deviation from the usual.

Color blindness seems to bear no relation to intelligence, so

that in drawing where color is used teachers will find a certain percentage of generally very able children producing absurd results. A color-blind child with a great gift for drawing, may succeed in etching or in black and white work of various kinds, as has been shown by the actual rise to eminence of etchers who are color-blind.

VI. ILLUSTRATIVE CASES

The facts which have been set forth in regard to ability in drawing will be further illuminated by concrete cases. In Figure 19 we have reproduced the psychograph of a child in the elementary school, E 1, showing talent in representative drawing combined with very inferior intelligence.

E 1 was a pupil in the sixth grade, at the time when this psychograph was made. She was nearly 14 years old, and therefore distinctly retarded in school status. In spite of her general incompetence, her drawing teacher placed her near the top of her grade in native ability to draw. The child is described as not original. "She can follow better than she can originate." "Apparently her talent for drawing is inherited. Her father is a tailor. He enjoys drawing and lettering. Her mother takes great interest in the children's drawings, and an aunt has made paintings of some interest. An older brother of E 1 is reported as very good (original and true) in drawing. She has also two younger sisters and a younger brother who are good in drawing."

Figure 20 shows a copy of a man's portrait, done by a 14-year-old boy, of IQ near 70. This boy was incapable of normal progress through the school curriculum. Being "left back" repeatedly, he became a truant and otherwise delinquent. His ability for and interest in drawing are highly specialized. Figure 21 shows drawings of movement (not copied) by the same boy.

Percentiles

Handwriting, School Marks

Drawing, School Marks

Drawing Cart

Drawing Horse

Cancellation

Cancellation Triangles

Perceptual Learning

Lincoln and Pig, Deferred

Lincoln and Pig, Immediate

Marble Statue

Th. Aesthetic Appreciat'n

Code 1-g

Punched Holes

Spatial Relations

Thurstone Hand

Thurstone Reasoning

Bonser Reasoning

Proverbs I, II, VI

Trabue J and K

Word Building

School Standing

Binet IQ

Percentiles

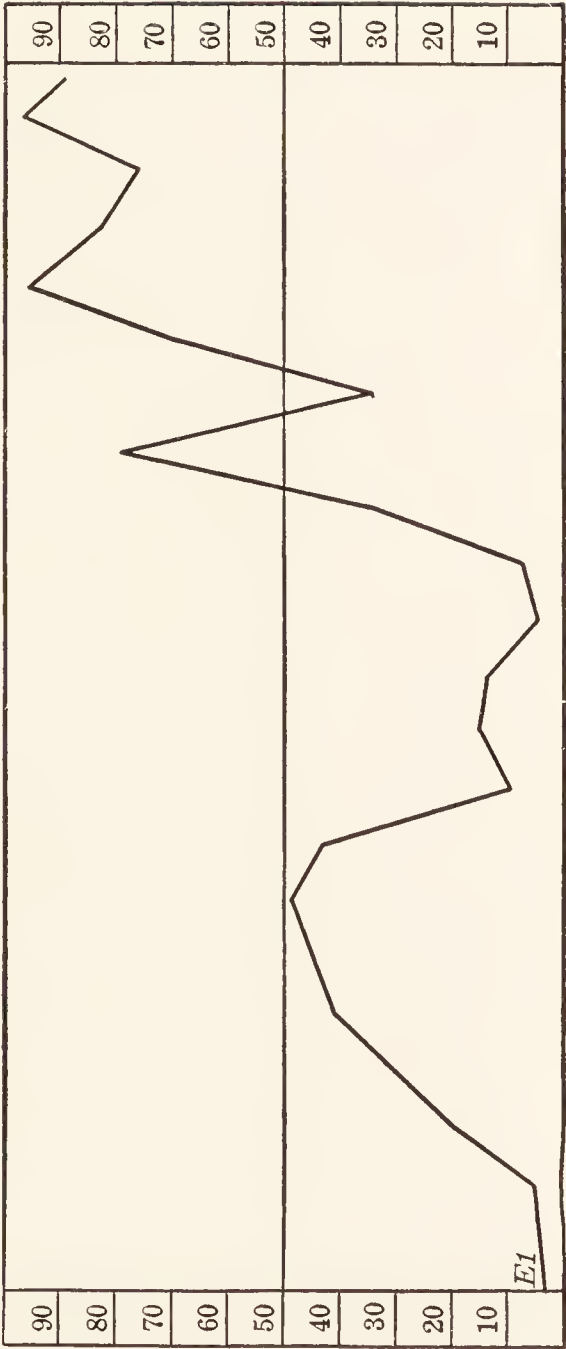


FIG. 19. — Showing the psychograph of a stupid child, who has a special ability in representative drawing. (From Manuel's *A Study of Talent in Drawing*. Reproduced by courtesy of The Public School Publishing Company.)

The special ability in paper-cutting of a feeble-minded man, "Dick," is illustrated in Figure 22. At the time these silhouettes were cut, this man was 28 years old, strong and healthy, with a mental level of 6 years 4 months, and IQ 39 (Stanford-Binet). He has been an inmate of an institution for mental defectives for seventeen years, as his general intelligence is insufficient for any kind of unsupervised career. He has never been able to learn to read or write.



FIG. 20. — Showing special ability in drawing, of a 14-year-old boy, of IQ near 70. The portrait is a copy.



FIG. 21. — Showing special ability in drawing of a 14-year-old boy, of IQ near 70.

This man is greatly interested in animals, and after being taken to the circus sometime ago, became a nuisance in his preoccupation with what he had seen there. In cutting the silhouettes, he merely takes a sheet of paper in one hand, a pair of scissors in the other, and cuts absolutely "free-hand," without reference to any preliminary patterning or draughting, either from memory or from a model. The performance is accompanied by many naïvely vain remarks, calling attention to his skill and the quality of the product. He can also draw, as is shown in Figure 23. He has never had any special training so far as known.

For the sake of contrast, we have presented, in Figure 24, the attempts of two university professors to cut an elephant from paper, as did "Dick" in Figure 22. These two professors are both doctors of philosophy, distinguished in their respective fields for research. Yet they are greatly surpassed by "Dick" in ability to cut silhouettes.

VII. INHERITANCE OF TALENT IN DRAWING

A comprehensive study of the inheritance of talent in drawing is yet to be made. Manuel took the family history of the pupils studied by him, and found artistic ability of some kind among close relatives in almost all cases. The gift showed itself in early childhood in these talented persons, and there is every reason to believe that it was bestowed by the conditions of near ancestry.

VIII. GENERAL SUMMARY

It is clear that talent for representative drawing arises from a happy combination of a great many variable functions; and that this combination may occur in persons of superior, average, or inferior intelligence. Likewise, conspicuous lack



FIG. 22. — Showing the special ability to cut silhouettes, of a feeble-minded man, inmate of an institution for mental defectives. See also Figure 23.



FIG. 23. — Charlie Chaplin pursuing a gentleman, and pursued by a policeman. Showing the special ability to draw, of a feeble-minded man, in an institution for mental defectives. See also Figure 22.

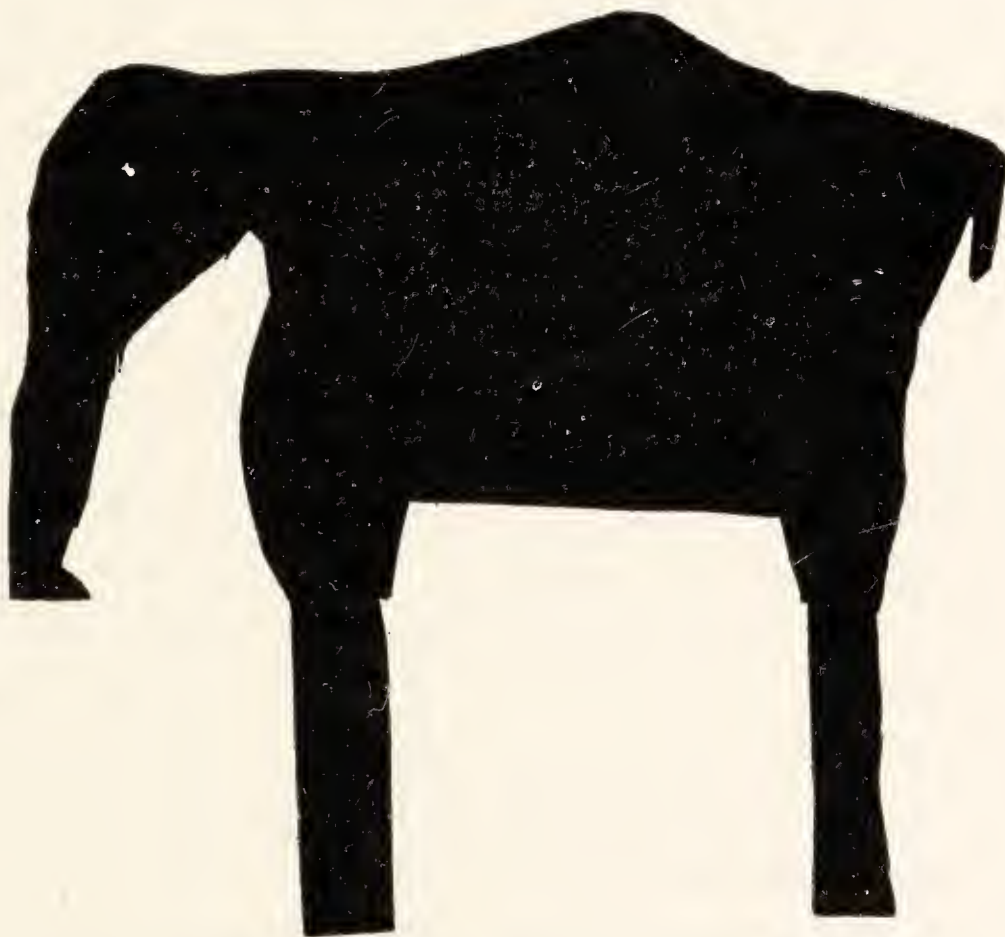
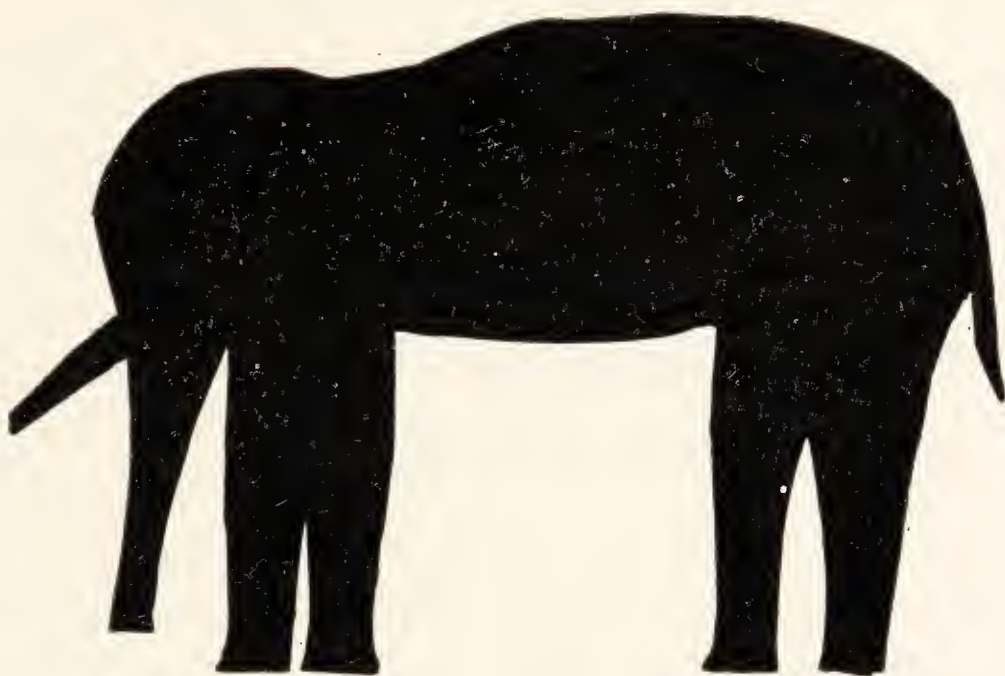


FIG. 24. — Showing attempts by two distinguished university professors to cut silhouettes of an elephant. Compare with Figure 22.

of this talent is compatible with intelligence of almost any degree. Therefore, many children considered by their teachers of drawing to be pupils of ability, will be rated as but mediocre, or as inferior, by other teachers. This will be true especially to the extent that drawing as a subject of instruction is limited to *representative drawing*.

Since superior students of science may or may not have ability to draw, it is probably undesirable that success in elementary courses should be made to depend largely on drawing.

Distinguished achievement in analytical, symbolic, and interpretative art is probably as incompatible with native stupidity as is distinguished achievement in any other field of technical endeavor. Persons who can draw, but are nevertheless generally dull, should probably not be guided toward the career of designer, architect, cartoonist, or portrait painter.

All persons possess in some amount each and every one of the capacities, which in rare and happy combinations constitute talent in drawing. The typical child possesses them in typical degrees, so that the majority can draw moderately well. Since in after life most children will enjoy the drawings of others more frequently than they will themselves draw, probably it would be of value to devote a relatively greater part of the curriculum in drawing to forming acquaintanceship with pictures. Interest in drawing, painting, or sculpture may be present without talent, but probably keen interest and talent are most often combined.

At present educational psychologists have before them the task of extending research, so that the word "probably," so often used in this discussion, may be replaced by "certainly." The accomplishment of this task will call for the coöperation of artists, in particular.

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CHAPTER VIII

MUSIC

I. WHAT IS MUSIC?

AMONG animals, only birds and men can produce music. Possibly, of these, men only can appreciate it. It is not agreed as to whether birds can appreciate music. They respond to it, and even imitate it, as in the case of the mocking bird, but we cannot be sure that their singing is for "pure joy," or for the love of the melody rendered. With the majority of men we know that musical tones arranged in melody or harmony act as original satisfiers, by and in themselves. "Music hath power to soothe the savage breast."

The analysis of capacity for musical performance, and the study of individual differences in this respect, were preceded by monumental studies of tone-psychology, rhythm, pitch-discrimination, and acoustics. In these researches psychologists, physiologists, and physicists have joined efforts. As Mead says in discussing Meyer's theory of melody, "The search for the basis of music is centuries old; it antedates the search for the philosopher's stone, the Holy Grail, and the North Pole."

Nevertheless, in spite of all their searching, scientific men have not discovered the basic psychology of harmony and melody. Meyer, a lifelong student of the problem, concludes that, "Where we hear a succession of different pitches, we are affected in a certain way which cannot be described, but has to be regarded as an elementary psychological fact." The satisfaction experienced by the typical person upon

hearing a harmony, and the annoyance experienced by him upon hearing a discord, remain among the mysteries, perhaps unfathomable, of human psychology.

II. THE VARIOUS KINDS OF MUSIC

There are many different kinds of music, requiring certain differences in psychophysical equipment for their execution, severally. For instance, singing requires certain equipment which may be lacking in a highly gifted organist. An organist must have characteristics which are possibly dispensable to the harpist.

To sing, to play the piano, to play the violin, to play the trombone, to compose a symphony, to write musical criticism — these are by no means all necessarily possible to the same person. A complete inventory of musical talent will rest upon knowledge of how all the various kinds of music are related as regards the capacities required in each, and of how the violinist may differ from the singer, and the drummer from the conductor of an orchestra.

III. THE ANALYSIS OF MUSICAL TALENT

Since about the year 1915, psychologists have turned somewhat from the study of the nature of music to the investigation of the musical person. They have raised the questions: In what way does the musician differ from others in his psychophysical equipment? Why are some persons unable to produce or appreciate music?

The pursuit of these questions led immediately to an analysis of musical talent, for it was evident at once that a great variety of subsidiary functions contribute to any kind of musical performance. These may first of all be classified under three general categories: (1) *the acoustic functions*, the abilities involved in perceiving musical sounds, (2) *the*

motor functions, the abilities involved in executing musical sounds, and (3) *the intellectual functions*, ability to interpret musical compositions, and to originate new ideas.

It is in the United States and in Germany that the significant studies of musical and unmusical persons have been made. Rupp, Bernfield, the Pannenbergs, Révész, Schussler, and Seashore and his students have all made contributions to the subject.

Révész studied children who were extremely gifted in music, and proposed that in analysing musical talent the following abilities must be considered: (1) to compose, (2) to reproduce, (3) to hear, (4) to remember musical elements, (5) to transpose, (6) to improvise, (7) to modulate, (8) to play at sight. In addition Révész stipulated that observations must be made with regard to intelligence, interest, and the "artistic nature" of the child. Later, in 1920, Révész proposed eight tests devised for the identification of the musical. These were for (1) the sense of rhythm, (2) absolute pitch, (3) octave recognition and transposition, (4) relative pitch, (5) harmony, (6) memory of a melody, and (7) playing by ear.

The most complete inventory of musical talent that has been proposed is that of Seashore, who, with his numerous students, has made the most important contributions in this field. Seashore would include tests of all the following functions in the complete musical psychograph:

I. Musical Sensitivity

A. Basic Capacities

1. Sense of pitch
2. Sense of intensity
3. Sense of time
4. Sense of extensity

B. Complex Capacities

1. Sense of timbre
2. Sense of rhythm

3. Sense of consonance
4. Sense of volume

II. Musical Action

Natural capacity for skill in accurate and musically expressive production of tones (vocal or instrumental or both) in

1. Control of pitch
2. Control of intensity
3. Control of time
4. Control of timbre
5. Control of rhythm
6. Control of volume

III. Musical Memory and Imagination

1. Auditory imagery
2. Motor imagery
3. Creative imagination
4. Memory span
5. Learning power

IV. Musical Intellect

1. Musical free association
2. Musical power of reflection
3. General intelligence

V. Musical Feeling

1. Musical taste: likes and dislikes
2. Emotional reaction to music
3. Emotional self-expression in music

Seashore has succeeded in devising, standardizing, and making available for practical purposes scales of measurement for five of the basic capacities of musical sensitivity. These are for pitch, intensity, time, consonance, and tonal memory. Research is under way to bring the other elements of musical talent similarly within the province of mental measurement.

Attempts to study movement as an element in musical talent are exemplified by the recent investigations of Gatewood and of Hansen. Gatewood studied finger-movement

in a number of persons, and found that there exist those who, even with great amounts of practice, do not approximate the speed and accuracy which others show on the first trial. However, the investigation of the motor elements in musical talent has not progressed as yet to a point that would enable us to make positive statements useful to educators; but it is obvious that for guidance they are fully as important as the acoustic elements are.

IV. RELATION AMONG VARIOUS ELEMENTS OF MUSICAL TALENT

Correlation has proved that sense of pitch and sense of time are largely independent of each other. Persons may stand high in one and low in the other. We know even now, therefore, that the elements of talent are independent or partially independent variables, and that excellence in one may be accompanied by inferiority in another. The successful musician is he who combines the necessary elements in high degree. Most children combine the elements in moderate or typical degrees of each, and are able to learn music and enjoy it in the ordinary manner. Only a few are capable of becoming professional performers. Schussler concluded that 5 to 10 per cent of the pupils examined by him might be justly classified as unmusical. A similar percentage would doubtless be classified as very musical, of whom a small proportion would be capable of outstanding musical achievement.

V. RELATION BETWEEN MUSICAL TALENT AND GENERAL INTELLIGENCE

It is somewhat difficult to compare musical talent with general intelligence, within a group of individuals, by test, because the tests which have been devised are to an extent dependent on intelligence for their execution. In order to

perform them, it is necessary to follow somewhat complicated directions, and to do this requires the exercise of intelligence. Seashore's tests cannot be reliably carried out with persons whose general intelligence level falls below about nine years.

Within the range of intellect which is sufficient for understanding and carrying out the directions, musical sensitivity as regards pitch, intensity, time, and consonance shows no reliable correlation with general intelligence. This is what we should expect from test results, on the basis of the relationships shown previously between ability in music and ability in school work on the whole. For instance, Schussler found that of pupils classified by his criterion (grades received in singing) as "unmusical," 41 per cent reached the grade norms in school work. Of those classified as "semi-musical," 57 per cent reached the norms. Of the "musical," 79 per cent reached the normal status. The average standing in marks of the "musical" fell 15 per cent above that of the "unmusical," while the "semi-musical" showed an average rating 6.6 per cent higher than the "unmusical."

When we consider that school marks in singing, as in drawing, are given not only for musical capacity, but for a heterogeneity of factors, including effort, attendance, ability to comprehend directions, and so forth, we should at once expect from these figures that by actual test, musical ability would be likely to show marked independence of general intelligence. Nearly half of the distinctly "unmusical" children reached or exceeded the grade norms, in general school work. This is not far from what is true of children taken at random, regardless of musical talent. That a disproportionately large number of pupils who did very good work in music reached or exceeded the typical performance in school work on the whole, might be expected from the ex-

tent to which school marks in music are probably given for general superiority of the organism, as suggested above.

The present findings from actual tests of sensitivity, above the minimum of intellect required for carrying out test directions, are that correlations closely approach zero as regards musical sensitivity and general intelligence. Therefore, educators may expect to find a number of pupils, who fail in nothing but music, and others who succeed in nothing but music. As Witmer has said, in discussing the specialization of musical gifts, "Were society so organized that success in life in every sphere of activity were dependent upon a good enough ear to turn a tune, many persons who are now doing useful work in the world, would have to be relegated to the class of imbeciles."

In view of the facts, the wisdom seems doubtful of requiring all teachers in the elementary schools to qualify in singing before being certified, as is now done in some places. There will be a goodly number of students, in the normal schools, who are fitted by original endowment to become excellent teachers, except that they will never be able to sing. In the case of a gift so specialized, it seems advisable to have a special teacher wherever possible, rather than to disqualify from teaching persons who cannot sing, but are otherwise well fitted to educate the young.

Tests show that musical talent is specialized, but this is not to say that eminence in music can be attained by the stupid. The achievement of eminence in any endeavor calls for a grasp of life situations and a farsighted fidelity to sustained effort, which are functions of general intelligence. Also, for eminence in a musical career the intellectual functions which have to do with composition and interpretation are doubtless indispensable. A survey of the general intelligence of eminent musicians would probably reveal a median well

above the average; and this would probably hold true even for singers.

VI. ABSOLUTE PITCH

By absolute pitch is usually meant the power to recognize a single musical note when heard, without comparison with any other tone, either objective or subjective. It seems to be an hereditary gift, and probably cannot be acquired by training. (Some doubt has, however, been recently cast upon the latter conclusion by the researches of Gough, who was apparently able to educate persons in this respect to a limited extent.)

Statements regarding the frequency of those who possess this idiosyncrasy vary, from that of Boggs, who says that only a few persons have the gift, to that of Seashore, who declares that "the ability to name notes of a familiar keyed instrument on hearing a single tone is rather common among trained musicians, and may show itself very early in childhood." Perhaps the discrepancies of statement arise through lack of complete agreement as to what should be meant by "absolute pitch." If the definition is insistently limited to that often given, namely, "the power to name a single musical note when heard, without comparison with any other tone," then no doubt the gift belongs to very few people, even those otherwise musically well endowed.

Seashore holds that in these cases, it is probably not pitch as such which is recognized, but rather the timbre of the note. "The timbre of the low notes is entirely different from that of the higher notes, and the evidence seems to show that it is easier to remember a characteristic timbre than pure pitch in itself."

The gift of absolute pitch is a great advantage to a musician. It is included as a valuable asset in the talent-inventory of Révész.

VII. TONE DEAFNESS

Certain anomalies of structure in the ear give rise to tonal "gaps" and "islands." The ear does not discriminate among pitches, in certain segments of the scale for pitch. Such a condition may occur in but one ear of a given individual, the other ear then hiding the defect.

The child who is extensively deaf to tones has, of course, no means, save the testimony of others, of knowing whether he is or is not singing properly (unless he sees his singing on a tonoscope). He cannot be taught to sing in key, because the receptors which would enable him to profit by training are absent from the structure of the ear. Many a tone-deaf child has doubtless suffered much from persistent, conscientious efforts to make him sing.

VIII. RANGE OF INDIVIDUAL DIFFERENCES

In a previous chapter it has been pointed out that quantitative psychology is still struggling toward the invention of scales which shall measure mental traits in terms of units, every one of which shall be equal to every other, as every inch is equal to every other inch. Until this is achieved, we cannot use "times as" comparisons in speaking of the relation of one individual to another, in respect to a function. We can now say that one person is three times as heavy as another person, because we can measure them in pounds, each one of which is equal to every other. But we cannot yet say that one person is three times as intelligent as another, because we have not captured the unit which would enable us to do so.

In some of the traits which go to make up musical talent, it is possible to use the "times as" comparison, because we have physical units whereby the differences may be gauged.

Pitch, for instance, may be measured thus. It depends physically upon the frequency of vibrations, proceeding from a sounding stimulus, and is measurable in terms of the constant number of double vibrations per second. Seashore has found variations in power of discrimination from one-fourth of a double vibration to fifty double vibrations per second. This means that there exist individuals who are at least two hundred times as sensitive as others to pitch, in terms of the physical unit.

Other elements in musical sensitivity cannot be so readily measured in stimulus units, so that the "times as" comparison cannot be made. The great diversity of sensitivity to pitch may, perhaps, be regarded as a token of the range of individual differences in musical sensitivity, especially since pitch is a fundamental capacity. It is probably no exaggeration to say that, in an ordinary class in the elementary school, children are being taught together, some of whom are at least a hundred times as musical as others. If children of the same age differed as much from each other in height as they do in sense of pitch, it would be impossible to teach them in unassorted groups, for some would be two hundred times as tall as others. The diversity in mental traits, so much greater than in physical traits, leaves us complacent, for the eye cannot behold the incongruities, as it can in physical matters. The eye cannot see the waste of time, effort, and joy which follows from the attempt to train, equally and together, children of such widely differing capacities for learning.

IX. CAN MUSICAL CAPACITY BE INCREASED BY EDUCATION?

1 Musical sensitivity is inborn, and probably cannot be increased in any respect by training. If the various elements are not present in amount and combination suitable for a

given degree of achievement in music, no course of training will supply the lack. This is not to say that ultimate achievement, for those who do possess capacity, does not depend on training. Achievement depends upon both training and capacity, but the latter cannot be supplied except by hereditary endowment.

The question of improvement through education becomes especially important in a case where the psychograph is excellent, but for one element. Much depends, of course, upon what the inferior element is, and the degree of the inferiority, as to whether the person will be able to succeed in a given musical career.

Inferiorities that appear in capacity for musical *action* are possibly much more susceptible to improvement by training than are inferiorities of *sensitivity*.

For example, there are persons whose psychographs show excellent musical talent, except that they falter from the pitch in singing. The voice may be excellent in range, quality, and volume, yet with a falter in control which leads to "flatting" or "sharping." This is a defect in musical action, an inaccuracy of movement.

It has long been known that the control of movement is brought about not only through the kinæsthetic sensations, but through aid from the other special senses as well. Vision is a first-rate aid to the acquisition of motor control. It is a more efficient aid than hearing, because much finer differences can be detected by vision. The problem, then, in an endeavor to improve by training those who "flat" or "sharp," is to devise some method whereby visual aid may be administered to control.

Such a method has been found in the tonoscope, an instrument which registers visually every pitch movement of vocal chords, or other sounding body. Practicing with the tono-

scope, the musician can see what his errors are, and learn what motor reaction will bring correction. The control of the eye is thus introduced into practice, as it is in tennis, writing, or other form of precise motor learning. Singers of all degrees of talent show improvement in pitch after practice with this instrument, and the improvement continues after the instrument has been laid aside. The gain made with the help of the eye remains in motor control, just as once having learned to write by aid of the eye, we can easily write in the dark or with eyes closed.

The susceptibility to improvement in other forms of musical action has not been shown experimentally, this whole field being practically unstudied as yet by experimental method.

X. THE INHERITANCE OF MUSICAL TALENT

The inheritance of musical talent has been investigated by Copp and by Stanton. The latter has made measurements of specific musical capacities in relatives of musicians, using Seashore's tests. This is the beginning of adequate study of the inheritance of musical talent, as the method, though laborious, is correct.

Four of the Seashore measures of musical talent were given to eighty-five members of six unrelated family groups, starting in each group with a person conspicuously known as a musician. These measurements were supplemented by a set questionnaire, covering musical endowment, musical education and training, musical activity, musical appreciation, musical memory and imagination, the questionnaire including a larger number of relatives.

From these data, a study was made of the tendency of offspring to be musical or unmusical, in accordance with parentage and more remote ancestry. The results show that musical talent is inherited, and the investigator believes

it not improbable that the formula of inheritance may be Mendelian. Much wider research would, however, be avowedly necessary, in order to establish the formula. It may or may not be Mendelian.

The offspring of a mating of musical with unmusical, of musical with musical, or of unmusical with unmusical, may thus inherit from either parent or from both parents, and apparently without regard to sex. Sex differences do not appear, either, in any of the tests of musical sensitivity, which have been standardized.

XI. PSYCHOGRAPHIC STUDY OF INDIVIDUALS

In order to illustrate concretely the way in which musical talent may or may not accompany other mental capacities, a few psychographic studies of individuals are presented, as follows.

The first is the psychograph of a girl, whom we may call G, aged 14 years. It shows her status in percentile ratings, on various mental and motor tests. G is of average, or typical, general intelligence, with superior rating in musical capacity, and in drawing.

G was brought for mental tests because she did poorly in the school where she was attending, receiving good marks in music and drawing only. The difficulty in keeping up to grade in general was readily explained, when the facts of school history were elicited. G was in a very exclusive private school, where the median IQ of the pupils is about 120, instead of 100 as among unselected pupils. This child, on account of the social status and educational traditions of her father's family, had been competing all her school life in a highly selected group of children, and was now considered dull by teachers, by parents, and by herself. All were astounded to learn of G's average intellectual capacity.

It may be remarked in passing that this is the school history of many an average child, born into a group where the family median is above the average. The problems of the son of an eminent man, who fails to inherit superior endowment and is but average in capacity, are especially acute, for he is usually

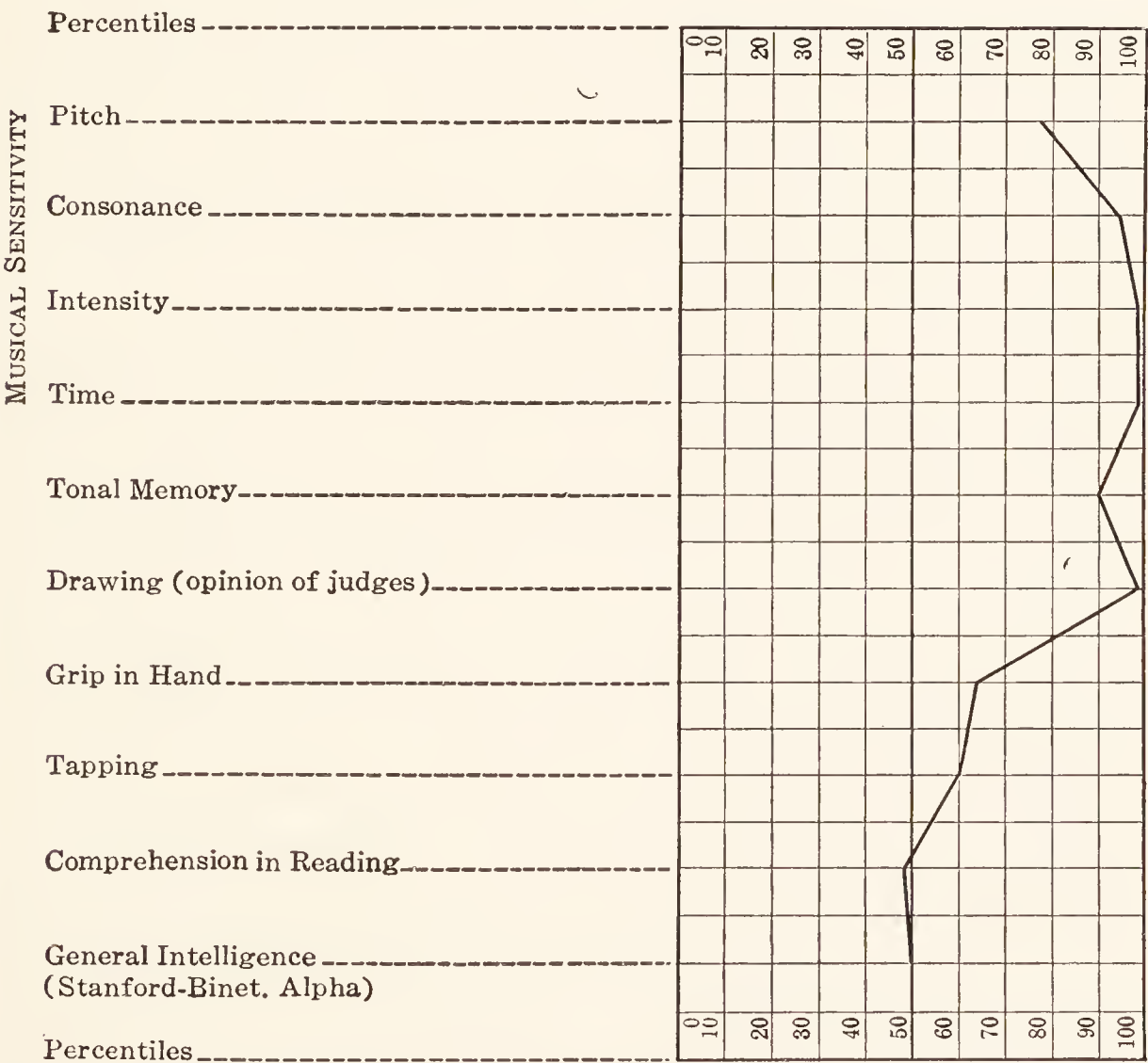


FIG. 25. — Psychograph of G, showing special ability in music and drawing. (Percentile values for speed in tapping, and strength of grip have been approximated by estimate.)

expected to undertake tasks for which he is unqualified by original nature. The miseries of a boy of average ability, expected from babyhood to pass through Harvard or Yale, the distresses of a girl of ordinary intelligence, destined openly from childhood for a college of very high standards, are peculiarly poignant to the person who sees human nature

in the light of all the facts which we have been recounting. The case of G, and scores of others like it in this respect, should lead parents to a policy of reticence concerning their expectations of their children, until it is certain that these expectations have a chance of being realized. Fortunately, the great majority of children of very successful parents never have a problem of this kind, because of the tendency to selective mating and the laws of heredity. Most of the children of gifted parents are themselves sufficiently gifted to perform the expected tasks as a matter of course. Not all children of gifted fathers are, however, gifted, because other ancestors, some of whom may be but average persons, are likely to contribute to the mental status of the child. Yet according to the customs of our country, it is usually the ability of the father that determines the social *milieu* and the educational tradition to which the children are subject. Thus, the son of a corporation lawyer, who has inherited the intelligence of a stupid but handsome grandmother and the educational traditions of a brilliant father, is in a sorry plight, unless the facts of human nature are expertly and sympathetically understood in his family.

In the case of G, the special talents in drawing and music, combined with average intellectual ability, made it possible to suggest very satisfactory adjustments. The idea of college was abandoned, and plans were made to pursue education in art and music, which had already been undertaken in a limited way, with excellent success. From the point of view of heredity, it is interesting to know that one of G's grandfathers, a chemist by profession, played a church organ every Sabbath as a recreation, and spent leisure hours making drawings, many of which are still kept as ornaments.

The psychograph of M shows special defect in musical capacity, combined with very superior general intelligence.

M, a schoolboy, was recently brought for mental tests at the age of 10 years, because of disagreement among his teachers as to his mental ability. The regular classroom teacher believed M should be given a double promotion because of his brilliant work in reading, arithmetic, and elementary science.

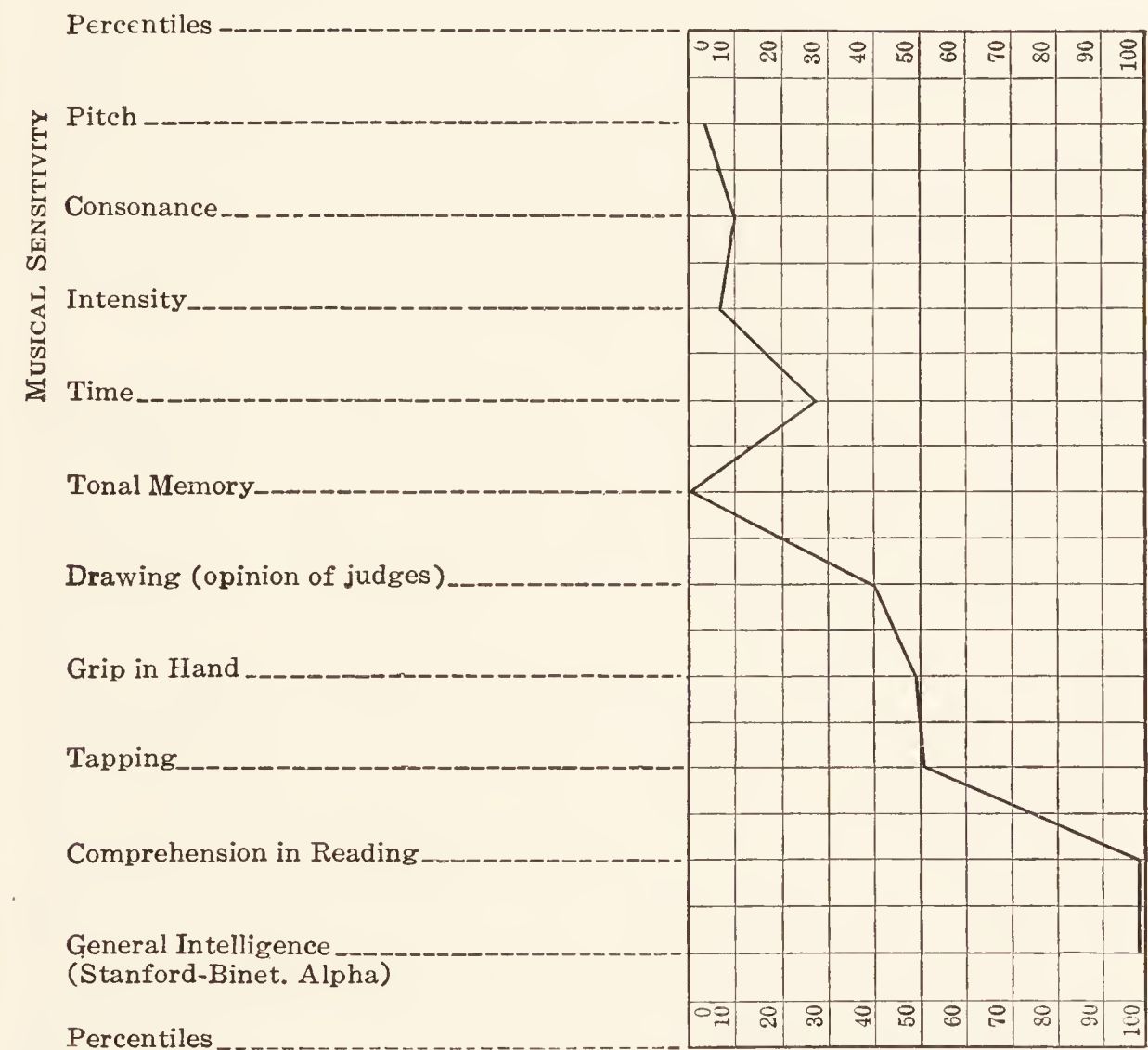


FIG. 26. — Psychograph of M, showing special defect in music, combined with very superior general intelligence.

The teacher of music held that he should repeat the work of the grade in which he then was, as an utter failure from her point of view. The shop teacher took a mid-way position, saying that his work seemed fair, and warranted promotion, but no more, to the grade above, in due order.

M's psychograph explains the differences of opinion thus expressed by teachers. It is seen that in intellect he ranks

well up in the top percentile of all children born, while in musical capacities he ranks in the lower percentiles. The difficulties in shop work arose from the fact that M is left-handed, and was at that time being trained into right-handedness by the teachers. This made him awkward in shop work, which he cordially detested.

M's IQ is 151, which accounts for his superiority in reading, science, and arithmetic. He will not be able to learn music, or to appreciate it, and to deprive him of his double promotion on this account seems contrary to his best interests.

XII. CAPACITY TO APPRECIATE MUSIC

Though it is probably true that those who can produce good music usually appreciate music also, the reverse need not be true. There are many who are sensitive to music and are greatly satisfied by it, who have not the ability to become musicians.

Music as taught in the schools is concerned chiefly with learning to sing. It would seem that some time might profitably be devoted to hearing good music, and learning to form preferences.

The keen satisfaction which comes to the extremely sensitive has been expressed by some of them in words. Schumann said of another musician, "He who has once heard Henselt can never forget his playing; these pieces still haunt my memory like the recollection of a parterre of flowers." And again, "The veiled enjoyment of music which one does not hear, has something magical in it." Berlioz has given us this glimpse of his delight: "Last night I dreamt of music, this morning I recalled it all and fell into one of those supernal ecstasies. . . . Believe me, dear friend, the being who could write such miracles of transcendant melody would be more than mortal."

Stanton questioned the talented and untalented relatives of musicians as to the rôle played by music in their daily lives. Many showing superior talent reported that music in some form seemed vital to their program of living. It was referred to by them as "a daily relaxation from business," "a great source of courage, a spiritual tonic," and as "absolutely paramount." One person used the word "hunger," in describing the longing which ensued upon being deprived of music. There may be people capable of such satisfaction in music, that they would choose between bread and music, if hard put to it, not without a struggle.

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CHAPTER IX

MISCELLANEOUS

I. SPECIAL FUNCTIONS WHICH HAVE NOT BEEN LONG STUDIED

THERE are various mental functions which are now thought to be largely special, which have not yet been studied sufficiently to warrant extended discussion of each, yet which merit notice as such if for no other reason than that attention should be directed to the desirability of studying their place in intellectual organization. Some of these, like chess-playing, will not be discussed here, as they are at present but remotely connected with prescribed education. We shall, therefore, comment upon but some of these, giving such facts and theories as are available in the case of each.

II. LEFT-HANDEDNESS

The hand is rated by students of the history of civilization as one of the most important determinants of man's rise from savagery. The loss of even a finger is a handicap recognized in such times of stress, as when men are drafted for war. With the great majority of people, the two hands are unequal in strength and accuracy, the right being the major member. With a small minority of children there is, however, a predisposition to use the left hand, instead of the right hand, as the major member. This is a special condition which must be taken into account by educators.

According to different investigators, the proportion of left-handed children ranges from 2 to 6 per cent. The dis-

agreements arise from the variety of criteria used and of populations sampled. The median figure of 4 per cent seems, for several reasons most probable, as the general proportion of left-handedness.

Many theories as to the origin of handedness have been formulated. It has been argued that handedness is not innate, but acquired from the mother's habitual method of carrying the infant on one arm rather than on the other, so that one of its arms is pinioned against the mother habitually, and gets comparatively little exercise. The theory has been advanced that since the heart is the most vital organ of the body, and is located on the left side, the shield to protect it was held by the left hand, permitting the right hand to attain greater dexterity with the spear, the advantage thus acquired being transmitted to offspring. Also, it has been proposed that the center of gravity of the viscera, the position of the subclavian arteries, cerebral asymmetry, and greater blood supply to one cerebral hemisphere may be, respectively, the origin of handedness. All of these theories are unsatisfactory, for reasons which have been well stated by the original investigators. There remains to be considered the proposal that handedness is determined by ocular dominance. The right eye is the better seeing eye in about 96 per cent of people. As vision develops long before muscular coördination in the infant, the proposal is that the hand is brought to coöperate with the dominant eye. The disproof of this theory is that among the congenitally blind the proportion of right-handed to left-handed is not materially different from that among seeing persons.

The origin of handedness is, therefore, not understood, and it is not known why about 4 per cent of the population should show dominance of the left hand. It must be considered that handedness is of many degrees, from extreme

right-handedness, through ambidexterity, to extreme left-handedness. All right-handed persons are not equally right-handed, and all left-handed persons are not equally left-handed.

Trustworthy studies of the heredity of handedness indicate that it is inherited. Ramaley studied 610 parents and 1130 children, and arrived at the conclusion that left-handedness is inherited (as a Mendelian recessive), and is potential in about one-sixth of the population.

It is obvious that modern appliances are adapted to the right-handed, and that right-handedness is regarded generally as "the way to be." Teachers and parents feel it their duty to compel the child to use the right hand.

Studies of left-handed children who have been "changed over" through education or accident to the right hand, and of right-handed children changed over through accident to the left hand, lead to the conclusion that among them there is more nervousness and a greater number of speech defects than would be allowed by the usual course of events. Stammering is evidently a complication in some cases of modified handedness. The physiology of this connection is obscure. In view of the fact that speech defects occur to so great an extent in "changing over," and that we do not know the physiology of handedness, it seems by all means wisest not to try to modify handedness where it is very pronounced. A very right-handed person, fortunate in being with the majority, may, by using for a week his left hand instead of his right, get an idea of what is suffered by a very left-handed child being compelled to use the right hand.

It has been reported that there is an undue proportion of left-handed persons among criminals, mental defectives, and the insane. These reports require careful verification. Criminals, mental defectives, and the insane have been much

more carefully scrutinized than have the superior in intellect and character, or even than the average population. The present writer has, during recent surveys, noticed left-handed performance repeatedly in very gifted children, but has not computed the proportion. Until further scrutinies have been made, it cannot be said positively that left-handedness is correlated with organic inferiority.

Perfectly satisfactory tests of handedness have not yet been agreed upon. Jones proposed some years ago to measure congenital handedness by means of a brachimeter. This is an instrument for measuring the bones of the forearm, and by its use Jones hoped to detect handedness "at the moment of birth" as well as on any subsequent day of life. These hopes have not been realized in the findings of others who have given the method fair trial, as Beeley did. Tapping, with the wrist movement, tapping with fingers, tracing, spontaneous rubbing, throwing and picking up, winding, and cutting with scissors are the most promising among tests so far tried out, to discover whether a child is congenitally left-handed. Gripping, as with the dynamometer, does not seem to correlate so well with known facts, as do the other tests of movement.

Left-handedness as an element in individuality becomes conspicuous in school procedure especially in writing, drawing, shop work, or any work where the hand is an important factor in the performance. It may become conspicuous in vocational endeavor, either as an asset or a handicap. In a few kinds of performance, such as baseball or tennis, left-handedness gives an advantage, all other things being equal. In most professional pursuits (with the possible exception of dentistry and surgery because of manufactured appliances) left-handedness is a matter of indifference. In work with machines left-handedness is likely to be a handicap, because

machines are "right-handed." Even scissors, eggbeaters, typewriters, and other common appliances of office and home are "right-handed."

Left-handedness as a handicap in the absence of rational consideration of it, is illustrated in an extreme fashion by the case of a young pickpocket, remanded for mental examination upon second offense. This boy was of average general intelligence, extremely left-handed, and a stammerer. He had left school as soon as the law allowed, with a record of chronic truancy behind him. He explained that he had always "hated school," because the teachers tried to make him right-handed, and because he was so ashamed of his stammering. Obtaining his working papers, he had first tried factory work, but the machines were all right-handed. He had then taken "a job" as an office boy, but he had to abandon that because he could not adequately answer the telephone, or converse with those who questioned him. Being "fired," he found a place as packer of china in a department store, but had a fight with a fellow worker, who mimicked him, and was dismissed. Soon thereafter, needing money, he saw an opportunity to abstract a purse from a convenient pocket, and did so. The success of this venture led to others like it, until he was apprehended and sent to the reformatory. Having served his time, he came out with this record added to his original difficulties, and drifted again into picking pockets.

The history of this boy shows the adaptation to social environment of an organism struggling by trial and error methods, without rational guidance. A left-handed man can pick pockets as well as anyone else (perhaps better), and speech defect is here no hindrance, since perfect silence is observed in such pursuits.

This boy might have had a very different career if school

and society had given a different kind of consideration to his individuality.

III. MIRROR WRITING

A certain number of children, variously estimated, write backwards, beginning at the right of the page. This is called "mirror writing," and is apparently a function of left-handedness. Baldwin's description is succinct.

"Mirror writing is the form of inscription which arises from tracing words with the left hand by an exact reduplication of the movements of the right hand, in a symmetrical way from the central point in front of the body, out toward the left. It produces a form of reversed writing which cannot be read until it is seen in a mirror. Many left-handed children tend to write in this way. Some adults, on taking a pen to write with the left hand, find they can write only in this way. Even those, like myself, to whom the movements seem, when thought of in visual terms, quite confusing and impossible, yet find when they try to write with both hands together, in the air, from a central point right and left, that the left hand mirror writing movements are very natural and easy."

Beeley conducted a survey, by questionnaire addressed to teachers, of the prevalence of mirror writers in the elementary schools of Chicago. He thus found one mirror writer to every 2500 children. Gordon by actual tests of writing found a larger proportion of mirror writers, about one-half of one per cent. Among feeble-minded children in special schools the percentage appears to be much greater, in fact, about seventeen times as great, according to Gordon's findings.

All investigators agree that mirror writers are almost always left-handed by test, though the writing may be done with the left hand, or with the right. As to the hand used in producing the writing there is disagreement among inves-

tigators. Gordon found that "the mirror writers were nearly always left-handed children who wrote with the right hand." Beeley says: "All of the mirror writers write mirror-wise with the left hand. The only instances of right-hand mirror writing found were a few upper-grade pupils who having seen this kind of writing naturally executed by mirror writers, attempted to imitate the same."

The origin of mirror writing is not fully explained as yet. It is probably the natural mode for left-handed persons, as attempts to write with both hands indicate. Yet not all left-handed persons acquire this habit. Obviously the mirror writer is not corrected in his fault by notice of the

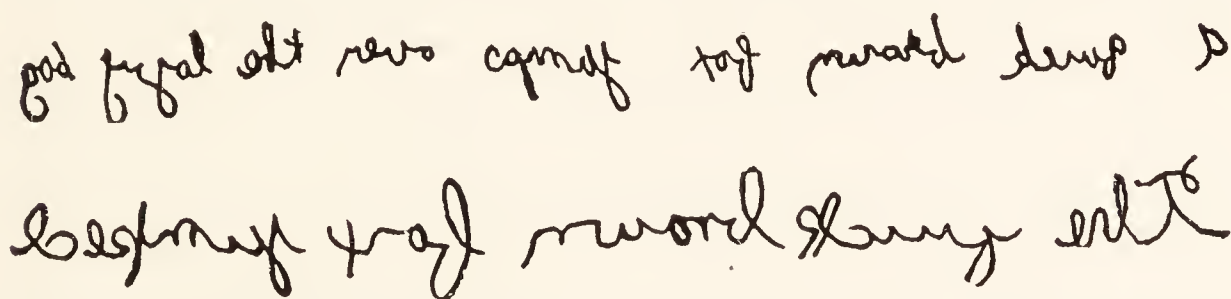


FIG. 27. — Showing mirror writing by public school pupils. (From Beeley's *An Experimental Study of Left-Handedness*. Reproduced by courtesy of the University of Chicago Press.)

discrepancies between the visual and the motor. It may be that those left-handed children who become mirror writers are usually deficient in visual perception of letters or words, or generally deficient. That there are, however, bright children who form this habit is shown by the surveys made.

Samples of mirror writing by school children are shown in Figure 27. In order to correct the difficulty, visual control of movement must be cultivated. Attempts to correct by changing over to the right hand are injudicious, for the reasons cited under the discussion of left-handedness.

In securing the control of visual perception and imagery, it is well to have the child write slowly and carefully from a copy, not being allowed for some time to write spontaneously.

At first, particularly, the teacher may guide the child's hands and urge him to notice in detail how another writes. Of course, the best educational treatment is that which never permits the development of the habit in the first place. This could be accomplished by careful watching of all left-handed children, at the very beginning of their attempts to learn to write. As each letter and figure is taught for the first time, the child whose natural impulse is to reverse it could be made conscious of his error, and could be drilled in the coördinations of hand and eye which produce the correct response. In the very large beginners' classes which are customary in the public schools, such careful attention to the needs of individuals is here, as in other respects, difficult to give.

IV. MECHANICAL ABILITY

In 1915 Stenquist, Thorndike, and Trabue, working with dependent children in a county of New York State, used tests of various mental functions, including a test of ability to put simple mechanisms together. These correlations showed that whereas tests of ability to handle language and tests of general intelligence (Binet-Simon) gave positive coefficients as high as .90, the test of mechanical ability yielded a coefficient much lower, when correlated with these. They therefore suggested that mechanical ingenuity might be a relatively specialized form of capacity, not reliably predictable from knowledge of general intelligence.

Subsequently, one of these investigators, Stenquist, made extended tests, and standardized a measuring scale to gauge mechanical ability. Measuring individuals for general intelligence and for mechanical ability, a positive coefficient of correlation amounting to about .40 is ordinarily obtained. This relationship is obviously not close. Ability to put mechanisms together is not reliably predictable from status

in general intelligence. The chances are, however, that a pupil who is superior in general intelligence will score higher in mechanical ability, than a generally stupid pupil will score. There is no negative or compensatory relation between the two functions, as is sometimes assumed.

Wider studies, including tests of *learning* mechanical processes, will give further light upon the extent to which ability to deal with concrete mechanisms coheres with general intelligence, and to what extent comprehension of mechanical principles is so correlated. It may be that the correlation between performances in Stenquist's tests and in tests like those used to measure general intelligence is reduced through factors like selective attention operating over a period of years. It may be that the relatively unintelligent become relatively more proficient in concrete acts, like assembling a bicycle bell or putting a lock together, because they have not the degree of intelligence that would enable them to prefer reading as an activity. Thus when 40 fifteen-year-old boys, 20 of whom have IQ's (Stanford-Binet) from 150 to 170, and 20 of whom have IQ's from 90 to 100, are faced with a series of tasks similar to those mentioned above, those of lower IQ might conceivably produce a record equal to or surpassing that of the first group, because their ability had enabled them to practice only tasks at a comparatively low level of *general* capacity. With an equal amount of attention to these matters, not previously of much interest to them, the boys of 150 to 170 IQ might surpass their competitors greatly. In a test of cake-baking, a hundred housewives, selected at random on a given date, will surpass the hundred most eminent men of science; but not after both groups have attended to the matter for an equal length of time.

The tests of mechanical ability do not as yet eliminate the

influence of mechanical *interest* upon the outcome of the test. Extremely high intelligence may well be relatively little interested in concrete materials and processes, preferring to manipulate ideas. Thus on a given date lower intelligence, long acting on that level, may surpass. Yet the higher IQ may really be capable under incentive, of surpassing in work with things as well as in work with ideas. Tests of *learning* mechanical processes would, therefore, be a most valuable supplement to what has already been done in this field.

Great inventors of mechanical devices are probably, as a group, very far above the average in general intelligence. This statement cannot be made with positive certainty, as the general intelligence of a large number of inventors has never been measured. It rests only on deduction from the fact that invention evidently calls for a high degree of selective thinking, and of interest in problem situations. Even "invention by accident" which may occasionally occur, calls for a high degree of ability to "notice" a new element in the familiar situation, in relation to other elements.

V. ABILITY TO LEAD AND HANDLE PEOPLE

It has been suggested that executive ability, in the sense of ability to deal effectively with human relationships, is specialized; that it is not closely correlated with IQ. Very few quantitative studies of the matter have been undertaken, largely because of the lack of means to gauge objectively "ability to handle people." It is true that there exist persons whose ability to deal effectively with human relationships has stood the test of life — executives in professional bodies, in business, and in government. These persons have not, however, been subjected to mental examination. Their time is so valuable that investigators perhaps hesitate to encroach upon it. Even if this could be done, we should nevertheless

lack proper data for correlational study. We should also need to know how many persons of an equal degree of intelligence had *failed* to succeed as executives. This would be difficult to discover.

Terman has given us a few facts, from his studies of superior children, which tend to indicate the relation between leadership and intelligence, in childhood. According to teachers' judgments of leadership, children of over 120 IQ are much oftener leaders than children of less intelligence are, and they are usually well liked by other children, even when not designated as leaders. Very few children over 120 IQ are judged by teachers to be "unpopular."

From observations of the frequency with which children of high IQ are leaders of other children, the present writer suspects that there is an optimum range of IQ, within which popular leadership is extremely frequent, but above which it is very improbable. The optimum range for leadership appears to fall between 110 and 130, when the total group has a median IQ of 100. Children of IQ over 160 seem to have little chance of leading their fellow children, when the median IQ of the group is 100. Children of IQ over 180 have almost no chance, in the observations of the present writer, to be popular leaders. Of the four New York children, previously mentioned in other chapters, measuring over 180 IQ (Stanford-Binet), only one is an organizer of fellow children, being designated by her teachers as "the most popular child in the school." This child functions as leader of a group of highly selected children, with a median IQ of near 120. In a group of unselected children she probably could not achieve leadership, although highly endowed with physical and temperamental traits which favor leadership.

Why should too much intelligence militate against the achievement of popular leadership? It is clear that in order

to organize and lead others, the individual must comprehend and share the interests of those led, and must in turn be understood by them. He must not consider their pursuits to be fatuous and without substance. They must not regard his interests as eccentric and unfathomable. Also, he must not experience too keenly the impact of the conflicting conations of those about him. To perceive and to experience too sharply the disappointments, misdeeds, punishments, and aspirations of others tend to disqualify for executive leadership.

The child of IQ over 160 tends to fall above the optimum range for leadership, for all of these reasons, in groups of unselected children. He is not interested in mumble-the-peg. They are not interested in the solar system. His interests are those of persons far beyond his age and size. But they will not accept his leadership because he does not "look like" a fitting captain for them. Thus only in very highly selected groups can such a child achieve leadership, that is, in groups which approximate his own IQ.

Too much intelligence thus tends to disqualify for executive leadership. The most intelligent persons born will usually be found leading only highly selected groups. Too little intelligence also undoubtedly tends to disqualify. It will be a nice problem to determine experimentally just what may be the optimum range of IQ for leadership of typical persons. Correlation is, of course, reduced by the various influences which we have been discussing. "Social intelligence" is in all probability not a specialized capacity, but merely an optimum section of the general intelligence curve (determined by ratio to the median intelligence of the led), combined with certain amounts of physical and temperamental traits.

These temperamental and physical traits are extremely important. The flighty, the unenthusiastic, the shy, the

overbearing, the ungenerous, the irritable are not well fitted to organize and lead, even when their intelligence is optimum. Likewise, the small, the commonplace in coloring, the undistinguished in features, the ill-kempt, the shrill of voice, are handicapped by their physical characteristics. The executive leader is he who combines optimum intelligence with enthusiasm, generosity, cheerfulness, and other favorable temperamental traits in the optimum degree, and who is large, forceful in manner and voice, and distinguished in contour and coloring. Facility in handling people and getting their allegiance, is due, therefore, to total personality, mental and physical, of which intellect is but one determinant. Correlations between executive ability and general intelligence will thus be greatly reduced from unity, because temperament and physique are far from perfectly correlated with general intelligence.

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CHAPTER X

INDIVIDUALITY AND EDUCATION

I. THE VALUES OF INDIVIDUALITY

IF we try to imagine what the world would be like if there were absolute uniformity among human beings, we realize anew the precious worth of individuality. It is marvelous that each one of us is unique. In all the generations there has never been another just like anyone, and there will never be exactly his like again. Each is, strictly speaking, irreplaceable.

By this inexhaustible diversity of mind and body life is faceted, and gives off sparkle instead of dullness. So far from being irritated by the idiosyncracies of our fellows, we ought to cherish their variety as a thing that makes life worth living. Instead of striving to force all children to learn the same things, at the same time, in the same way, because that would be cheap and convenient, we ought to foster individuality in its socially valuable aspects, so that the charm of human contact may be increased. To the connoisseur of human nature, the suggestion that all children be reduced to similarity is as dreadful as the suggestion to the connoisseur of art that all pictures and intaglios be turned out identical, by a uniform factory process.

Nor is the value of individuality limited to the æsthetics of personality, and to social intercourse. The economic peculiarities of the world, as we have it, permit the exercise of abilities in great variety. Organized society needs and will use capacity of all degrees, from that of a man who can load

sand on a carrier, and be satisfied thereby, to that of the man who can with satisfaction work out a new theory of inflammation, or construct a drama to interpret existence anew.

Failure to know the facts concerning the distribution of mental traits, the organization of intellect, and the laws of heredity and variation, leads to much wasted effort on the part of all who deal by profession with people. The most frequent error is that of demanding that others adopt one's own religious beliefs, standard of living, reaction time, or politics — usually with the idea that they will be greatly benefited thereby. Another common error of theory is that general happiness would be increased if some force could be established great enough to hold all down to the same plane of work, leisure, and reward. In education it has been assumed that justice would be well served by prescribing the same curriculum, at the same rate, at the same time, for every child.

If the uniformity of thought and action, to which these theories and practices tend, could be secured, the result would be deadening. Such uniformity cannot, however, be achieved, because of the biological forces of heredity and variation. The formulæ governing the interplay of these forces are little known, and they therefore lie outside of human control.

Many thinkers believe that nothing would be lost and much be gained for human welfare, by cutting off the variants who fall low in intellect and stability, and by increasing the number of those who fall highest, on the curve of distribution. However, it is possible to take, and perhaps to defend, the view that this would be meddlesome rather than helpful. Civilization becomes complex through the discoveries and inventions of superior deviates. It was they who invented wheel and lever, clock and calendar, court and statute book. They discovered the use of electricity, gravity, and steam.

When moral life and industrial life become very complicated, great numbers of men are unable to meet the situations devised, and perish mentally, morally, and physically. Law may become so intricate that only the steadiest can suffer its restrictions. Mechanical and chemical contrivances may grow so numerous and complex that typical human nature cannot cope with them. Would it be better, then, to end invention at its source, by eliminating superior deviates? Or would mankind thereby lose other gifts, wholly benign for all, which only the superior deviate can bestow? In the absence of the highly-endowed, would there not be a return to barbarism? And, if so, would the greatest good of the greatest number be thus promoted? Or should the welfare of the majority give way as a social ideal to the welfare of the best — the most capable, the most upright, the most enduring? Is it possible to evolve a social order in which the greatest good of all can be well served, since biological inequalities are so very great? These are questions for social and educational philosophy.

Men of science labor to acquire the knowledge that would give power to alter, at will, the shape of the curve of distribution for mental capacities. Such knowledge might work more changes in the world than have been wrought by knowledge of chemical formulæ or of electricity, but its right use would call for a wisdom and philosophical foresight which men at present probably do not have. The conditions and the theories that confront us in education call on us at present, as a matter of fact, to provide for the whole enormous range of capacities, general and special.

II. COMPULSORY EDUCATION

It is useful to recall that for centuries after mankind reached a point where prolonged formal education was available,

attendance upon instruction was voluntary. Those who wished to learn what could be taught of the arts and sciences, hired tutors. It is true that the public ceremonies may, perhaps, be considered to have represented compulsory education, even in primitive times. However, education in the sense of several years of devotion to learning what men have previously done, thought, and devised, was formerly a private matter. The educated, who could communicate by writing, calculate in large numbers, see the present to some extent in the light of the past, and engage in even more complicated intellectual work, formed a small and highly selected group. They were individuals who loved learning, and their median IQ was doubtless far above 100.

As the white peoples of the earth, in parts of Europe and America, accumulated wealth, and more and more of those who cared to do so could buy education, political power began to be decentralized. Generous men of high intelligence conceived the idea that government should be representative. Political democracy with manhood suffrage was established in the United States. It was then seen that political democracy cannot be sustained on the basis of private education, and public money was appropriated to establish public schools.

Merely to establish free schools did not, however, solve the problem of education for a democracy. The leaders of thought and action found that not only must opportunity be provided, but many must be forced to take advantage of it. Compulsory education laws were therefore passed in many of our states, and they stand upon their statute books to-day. Truant officers became a part of the regular school staff, their duty being to apprehend all children between statutory ages, and bring them forcibly to school. The City of New York, for instance, now supports 308 truant officers,

who are constantly kept busy by future citizens who wish to avoid education.

Why do they wish to avoid education? The reasons are various. Some of them avoid school because they have not enough clothing to wear; some because their parents need their earnings; some because they are ill; some because they are temperamentally unsuited to school discipline. The most important single cause of truancy is, however, that the curriculum does not provide for individual differences.

The curriculum upon which all children are now required by law to attend, is that which was formulated when only a few selected children were educated. Our schools are reading schools, and they teach abstract subject matter to a very great extent, much of which has no tangible relation to the life of many children. Children of IQ over 120 take pleasure in the abstract subject matter of grammar, mathematics, geography, and history. Children of IQ under 80 are made miserable thereby.

Not only is the curriculum not adapted to individual differences in general intelligence, but it is far less adapted to individual differences in special defects and aptitudes. The child who can never learn to sing is compelled nevertheless to pursue singing, even after school hours. The child who cannot learn reading by the method generally used is still treated by that method and no other. The schools were established with an undifferentiated curriculum, which they have tried to force upon intellects of an enormous range of diversity. Their purpose, so benign, has resulted in extraordinary cruelties and wastes.

III. THE IMPORTANCE OF GENERAL INTELLIGENCE FOR SCHOOL PROGRESS

If we examine mentally the large numbers of retardates in any public school where attendance is compulsory, we find

that by far the majority of them are inferior in general intelligence. A child of superior general intelligence (IQ) is seldom found among retardates. Of children of 120 IQ and over, Terman reports that they are almost invariably at least up to grade. Whatever the vicissitudes of fate — illness, absence, special disability — a child of superior general capacity manages to hold his own, at least.

It is not true, however, that the superior child is allowed, under the undifferentiated curriculum, to make full use of his power. He is compelled to slow down to the typical progress of his group, and to use only a portion of his capacity for learning. It is rare to find a superior child who is doing “a full day’s work” in school, because the tasks assigned do not call for maximum effort. Superior children could easily do much more than is allowed.

General intelligence is, then, the single most important factor for school progress. The same may be said of progress in vocational careers. The life success of a human being may be said to depend upon general intelligence, character, health, and opportunity (including the factor of sex). If any of these factors is reduced to zero, so that the individual is totally lacking in intelligence, character, health, or opportunity there can be no achievement. The order of importance of the various factors is probably that in which they have been mentioned, with general intelligence certainly at the top of the list. Intelligence may create character, opportunity, and even health, but none of these can create intelligence.

IV. SPECIAL ABILITIES AND DISABILITIES AS DETERMINANTS OF SCHOOL PROGRESS

As before stated in these pages, no census has ever been taken of special aptitudes and defects, in the functions which we have been discussing, and which are important for prog-

ress through the elementary school. No one can tell whether any have been advanced on the basis of a special gift. No one can say how many children are retarded, because of a specialized disability, though we know from reports rendered, that some pupils become retarded in school status through special failure in one or two respects.

The children described under the topics of special retardation in reading and in arithmetic, in this volume, are illustrative of the way in which specialized defect contributes to retardation in school status. Without passable mastery of these "tool" subjects a child cannot proceed through the elementary school. His progress is halted, much as it would be if he were deficient in general intelligence.

It is quite possible, on the other hand, that children may be occasionally overrated as to intellect by teachers, who are deceived by conspicuous talent in a special function. Coy, who studied for two years a class of highly intelligent children in Columbus, has given an account of a boy who was thus overrated. When the children were being selected for the special class described, this boy was sent by his teacher to join the group. She considered that he must be "very bright," "since he could draw cartoons, play the ukelele, and sing." He was said by the art teacher to have more ability than any other child in the building. He was retained in the special class by the investigator, but he was not able to do good work there. His IQ on three annual testings stood as 114, 119, and 120. (The other children in the group possessed general intelligence clustering about an IQ of approximately 135.) This boy surpassed the others in music, acting, and drawing, but "his ability to reason was far below the class level," and he could not compete successfully in general intellectual work. His teachers had been misled by his special gifts to recommend him as a child of surpassing intellect.

V. EXPERIMENTAL ATTEMPTS TO INDIVIDUALIZE EDUCATION

Official administrative recognition of individual differences among public school pupils began with the extremely stupid, whom we call feeble-minded. This was natural, because the feeble-minded are incapable of even approximately normal progress, and this, added to their tendency to become disciplinary problems, renders them an intolerable burden to teachers in the regular grades.

As long ago as 1872 we find that attention was called to the "pedagogical misfits," in proceedings at professional teachers' meetings in the United States. By 1890 the city of Cleveland had established two special classes for children presenting particular difficulties of discipline. Special classes for extremely dull children (the feeble-minded) have passed the stage of experiment. They are now an accepted part of the school system of many cities in this country, and a few state departments of education have undertaken to establish such special classes for districts not so favorably situated as cities are. The relative money cost of thus educating the most stupid children produced in our population is great, and the returns upon the investment are uncertain. We need careful studies of the cost of educating the dull, as compared with the cost of educating the superior, in the light of the returns from education, both to the public and to the individuals taught. The complexity of such study calls for much patience and ingenuity.

Special classes for children of very superior general intelligence, who are as far above the average as the feeble-minded are below, are at present much discussed by American educators. Such classes have actually been established in a few school systems. These are still considered to be experimental, but it surely will not be very long before official adminis-

trative recognition will be widely given to the needs of pupils whose natural rate of progress is over twice as rapid as that of the average child. Abroad, Germany has already undertaken education for gifted children as a special project of the public schools, in recognition, no doubt, of the extent to which national rehabilitation will be dependent on the training of the able. Contrary to pre-war policy, German educators are now seeking, by the method of mental tests, for superior mental endowment regardless of social-economic status, and even to some extent regardless of sex.

In general it is true that the provisions in the United States are for deviates so extreme in all capacities that their maladjustment to typical procedure creates a troublesome school problem on the one hand, and on the other a burden to the conscience of those who administer education. Classroom teachers demand that special attention be given to those who are chronically unpromotable and out of order, while educational psychologists insist upon the waste of ability that ensues from allowing gifted children to idle through the curriculum. For deviates of less degree there is not much provision. A few cities, of which Oakland, California, may be mentioned as an outstanding example, have adopted a three-rates-of-progress system, in which the children of typical ability (the great majority) proceed at a median rate, the lowest quartile (exclusive of the very lowest percentile) proceeding more slowly, and the highest quartile more rapidly. The system provides a flexibility far in advance of the ordinary one-rate-of-progress system, allowing for individual differences in general intelligence.

Little attention has been given as yet to the matter of individualizing public education for children who show special talents or defects. Some years ago the superintendent of schools in Munich requested the teachers of certain grades

throughout the city, to ask each child to draw two sketches: one from a model, and the other a free sketch. These were sorted for the purpose of finding exceptional talent in drawing. A certain per cent of the children showing this special gift were sought out and encouraged. Particular attention was given to the development of their talents.

Similar instances of official attempts to gauge and foster special talents are extremely rare. The experiment at Winnetka, Illinois, is of this order. In Winnetka there is a flexible promotion system, wherein pupils "pass" in a subject whenever they have completed the work therein. A pupil may be in different grades in different subjects. His whole school career need not be jeopardized by a single weakness, and if he has a special strength he is permitted to develop it as original nature would dictate.

At first thought it might seem that a public school system would be thrown into confusion by such a scheme. In Winnetka there are thirty to thirty-five pupils in a classroom. How can programs be arranged to suit the needs of deviating children, without much extra equipment?

Here it is necessary to recall that the majority of these children are *typical*. The middle 50 per cent of all children born deviate but slightly from the type of the race, in all their mental functions. They do not call for special adjustments. On either side of these, deviating more widely toward less and greater, run the remainder of the children, in very rapidly decreasing frequencies. Those who need a very wide latitude in school organization constitute possibly 20 per cent of all, the highest 10 per cent, and the lowest 10 per cent, in general or special capacity. The problem does not seem so vast, when we recall the shape of the curve of distribution, and the comparative infrequency of extremely unusual children.

VI. THE COST OF FOSTERING INDIVIDUALITY

The cost of individualizing education acts as a deterrent, even when the desirability is fully recognized. Compulsory education for all the children of all the people is expensive. A nation must be wealthy in order to carry it through. To maintain every child born into the social order for fourteen to sixteen years without earnings, and to pay from public taxation for his education for eight to ten or more of those years, is an enterprise upon which few societies of any time have ventured. Nevertheless, if democracy is to survive, and especially if it is to improve, as a form of government, universal education on a large scale is basic. Self-government, in the highly complicated environment which has been evolved, depends on literacy and other knowledge, requiring long instruction, even for youth of average ability.

What then of the great numbers of those who deviate in various degrees below the average in capacity for learning? The social order needs and will utilize their services. The economics of their presence in the republic is not a much more difficult problem than under other forms of government. It is the politics of their presence that causes concern under a democracy; for they are enfranchised, yet without learning they are political dependents. They stand at the mercy of any catch word tossed at them, with results which have raised on every hand an earnest searching of democracy.

For example, this question has been raised: Is it possible for education to prepare the lower half of the distribution curve for self-government? Considering recent discoveries as to the mental capacity which characterizes the lower half of the population when adult, is it possible that education will ever be able to nullify the charlatan influence of demagogues, whose appeal is to prejudice and cupidity? These questions remain unanswered. In the meantime the great

experiment of compulsory education is under way. The expense of it is kept down by teaching the children in large groups of thirty to fifty or over, the same lessons, in the same way, at the same time.

What would be the actual money cost of providing for individual differences in capacities, general and special? Few data to answer this question have been furnished. In Winnetka the cost of education is reported as not increased. This condition is doubtless exceptional. As previously stated, the money cost of individualizing education for the feeble-minded has been considerable. We have the figures from Cincinnati, and we derive from them that the cost of educating a feeble-minded child (one falling into the lowest one or two per cent in the distribution of general intelligence) in a special class, is over twice as great per annum as is the cost of educating an average child in the regular grades. For a feeble-minded child in a special class in Cincinnati, during the year 1917 to 1918, the money cost per annum was \$83, while for a typical child in the regular grades it was \$35.

The increased cost results from the fact that when education is individualized, the number of pupils occupying a room and taught by a teacher is about fifteen, instead of the regular number of thirty to fifty. If, roughly, 20 per cent of all pupils deviate from the typical so extremely as to require a considerable amount of individual instruction for their welfare, it is difficult to see how they may be well served without a considerable increase in the money cost of education.

Can the public afford to pay more than it now does? Investigations to answer this question are under way on a large scale. We need to know what our country can now pay, in order that we as educators may not commit the folly on the one hand of urging unwarrantable expenditure, nor on the other hand of failing to ask the appropriation of all that can

be spared for the development of individual capacity in the nation's children.

VII. THE PROBABLE REWARDS OF INDIVIDUALIZING EDUCATION

Even the money returns from scientifically differentiated education would probably be great, aside from the increase in children's happiness, in teachers' enjoyment, and in adults' satisfaction. The tangible values of individualized training might be nearly as great as its intangible values.

When we reflect closely upon the source of wealth, we see that it comes from the attack of intellect upon the environment. Apes have no wealth. Man has wealth only in so far as he acts upon selective thinking in regard to his environment. A society gains wealth only in so far as it permits and encourages the use of innate capacities for attack upon the environment, which lie unequally distributed throughout the juvenile population. Any theory of wealth that fails to ground itself upon this fact will but destroy those who seek to practice it.

No nation has ever yet shown what the full reward might be of adapting education to individual differences. Such a demonstration has been impossible hitherto, if for no other reason than that there was no known method of gauging children's abilities scientifically.

In the older social orders, where education was or is caste-bound, it is highly probable that on the whole education was and is more fairly adapted to individual differences than it is with us. Those barbarians who had much capacity for abstract thinking achieved by trial and success high-caste status, of which they ultimately became conscious. The aristocracy of older countries was not established by forces outside of human nature. The nobles were in the first place those who rose to power because they were stronger, more enduring,

and more capable of thinking than average men. Caste grew out of human nature itself. The majority of the nobles' children were capable by heredity of abstract thinking, and of acquiring the education, which came finally through centuries to be provided for them. The majority of those who failed to achieve high-caste status before it became recognized as such were doubtless chiefly individuals who produced descendants, on the average ill-adapted to profit from the kind of education established for the children of the higher castes.

In Great Britain, for example, where social organization was and is frankly based in theory and practice on caste (upper-caste status being, however, constantly kept open to adults of unusual achievement), Burt found that boys of upper-caste family, attending an exclusive high-class school, surpassed in all respects, in mental tests, sons of middle-class parents, of equal age, attending common schools. It is necessary, though outrageous to our prejudices, to face the fact that, in our own country (where caste is despised in theory and to some extent in practice), the median capacity of pupils in expensive private schools is well above the average of the juvenile population at large.

Caste-bound education in older civilizations recognizes innate individual differences to a considerable extent. Its injustice is that it does not recognize them completely. Caste takes account of individual differences due to heredity, but it does not regard those due to variation. Caste neglects to provide for the overlapping which occurs among the children of parents of different achievement levels. In a society founded formally on caste, there is no way provided for the appropriate education of gifted variants who occur in the lower castes, and for those of inferior ability born into the higher castes. Artificial barriers to natural achievement have arisen, because the consciousness of superior status was ac-

accompanied by jealousy of it as well. Revolt against this injustice to the minority (not recognized, however, as minority by the rebels) led to the opposite injustice, which we see practiced in the schools of our own democracy.

In the United States the theory was adopted that all men are created equal. All children must, therefore, be required to take the same education. Such a system violates individuality even more painfully and wastefully than the despised caste system of the older countries does.

As scientific psychology improves the methods of testing for individual differences in children, it will become possible to educate each one according to his capacity for learning. It will be possible to conserve and develop the special aptitudes of every child, regardless of race, sex, or circumstance. The humiliation and despair of chronic failure at prescribed tasks unsuited to capacity may be spared every child.

Thus we come again to consider tests of innate educability in *The Republic*: "We must watch them from their youth upwards, and make them perform actions in which they are most likely to forget or to be deceived, and he who remembers and is not deceived is to be selected." That will be the way.

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